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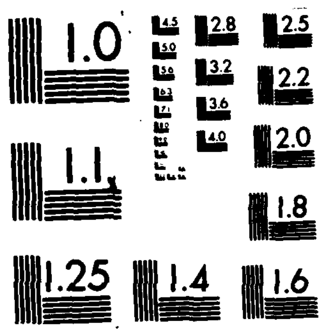

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FINITE ELEMENT MODEL FOR NONAXISYMMETRIC STRUCTURE WITH RATE DEPENDENT YIELD CONDITIONS

Prepared by

University of Illinois
Aeronautical and Astronautical Engineering Dept.
Urbana, Illinois 61801

February 1984

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT CENTER
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A previously derived model of rate-dependent plasticity is modified for use in a finite element stress analysis code. The code allows nearly axisymmetric bodies to be analyzed by a perturbation of the symmetric solution. It contains anisotropic yield conditions. The formulation of rate effect is added to the code and a test problem of a uniaxial tensile experiment is solved. Convergence to the exact solution is shown.

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I. INTRODUCTION

The objective of the present investigation is to develop a finite element model and computer program for the purpose of handling elastic-plastic material with rate-dependent yield conditions.[1] The effort is in two parts. The first part involves the analytical development in which the appropriate incremental, stress-strain relations are developed. The second part of the effort involves developing a finite element computer program which incorporates the analytical development. This computer program will be based on previously developed, approximate three-dimensional elastic-plastic computer code, SANX.[2,3] The code SANX is designed to perform structural analysis on cylindrical configurations which are approximately axisymmetric and which have definite nonaxisymmetric features. The code SANX was developed both for elastic and elastic-plastic materials with no time dependent properties.[2,3]

The starting point for the development of a three-dimensional finite element code is the one-dimensional analysis[1] which formulates the visco-plastic response in terms of the effective plastic strain. This approach is extended to the development of the three-dimensional model in the present investigation.

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1. W.H. Drysdale, "A Theory of Rate Dependent Plasticity," Ballistic Research Laboratory Report, APG, MD. (Forthcoming)
2. A.R. Zak, J.N. Craddock and W.H. Drysdale, "An Elastic-Plastic Analysis of Non-Axisymmetric Structures," International Journal of Computers and Structures, vol. 10, pp. 841-846, 1979.
3. J.N. Craddock and A.R. Zak, "An Approximate Finite Element Method of Stress Analysis of Non-Axisymmetric Bodies with Elastic-Plastic Materials," Technical Rept. UILU-ENG 79 0501, Aeronautical & Astronautical Engineering Dept., University of Illinois, Urbana, March 1979.

II. RATE DEPENDENT MATERIAL MODEL

The rate dependent plasticity model was introduced for isotropic material and used in the analysis of uniaxial stress case.[1] The same model will be used in the present investigation with a slight modification to allow for use with orthotropic materials[2,3] when needed. The yield condition for orthotropic materials will be represented by Hill's criterion[2] and this reduces to the octahedral shear stress criterion in the limit for isotropic materials.[1]

Using the rate dependent model for the yield criterion[1] the yield function is taken in the form:

$$f(\sigma_{ij} - \alpha_{ij}) = K(\dot{\varepsilon}^p_{ij}) \tag{1}$$

where α_{ij} represents the strain hardening parameters. The rate dependence is defined by the function K which is represented by:

$$K(\dot{\varepsilon}^p_{ij}) = [1 + b\ln(1 + \dot{\varepsilon}^p/\dot{\varepsilon}_o)]^2 \tag{2}$$

Equation (2) is an empirical formula which contains material constants b and $\dot{\varepsilon}_o$. The dependence of K on the rate is through the variable $\dot{\varepsilon}^p$ which will be defined later as the effective plastic strain rate. It may be noted that for isotropic material[1] the function K in equation (2) is multiplied by the square of the uniaxial yield stress at zero rate. In the case of the orthotropic material there are, in general, six yield stresses and it is not possible to separate one stress from the yield condition. The six yield stresses are included in the function f on the left hand side of equation (2).[2] Using equation (2) to represent rate dependent yield condition for orthotropic materials implies an assumption that each yield stress is dependent on the rate by the same relation to the effective plastic strain rate.

The next step in the development is to obtain an incremental stress-strain relation. From the plastic flow rule the plastic strain changes are related to derivative of yield function[2]:

$$d\varepsilon^p_{ij} = d\lambda \frac{\partial f}{\partial \sigma_{ij}} \tag{3}$$

Using the definition of kinematic strain hardening:

$$d\alpha_{ij} = C d\varepsilon^p_{ij} = C d\lambda \frac{\partial f}{\partial \sigma_{ij}} \tag{4}$$

where C is the strain hardening parameter.[2] During the incremental plastic deformation the stress and strain changes must remain on the yield surface and, therefore, from equation (2):

$$\frac{\partial f}{\partial \sigma_{ij}} d\sigma_{ij} + \frac{\partial f}{\partial \alpha_{ij}} d\alpha_{ij} - \frac{\partial K}{\partial \dot{\varepsilon}^p_{ij}} d\dot{\varepsilon}^p_{ij} = 0 \tag{5}$$

It can be shown[2] that:

$$\frac{\partial f}{\partial \sigma_{ij}} = - \frac{\partial f}{\partial \alpha_{ij}} \tag{6}$$

and, therefore, combining equations (4) and (6) with (5) gives:

$$\frac{\partial f}{\partial \sigma_{ij}} d\sigma_{ij} - Cd\lambda \frac{\partial f}{\partial \sigma_{ij}} \frac{\partial f}{\partial \sigma_{ij}} - \frac{\partial K}{\partial \dot{\varepsilon}^p_{ij}} d\dot{\varepsilon}^p_{ij} = 0 \tag{7}$$

Solving for the parameter $d\lambda$ from equation (7):

$$d\lambda = \frac{1}{C \frac{\partial f}{\partial \sigma_{ij}} \frac{\partial f}{\partial \sigma_{ij}}} \left[\frac{\partial f}{\partial \sigma_{ij}} dK_{ij} - \frac{\partial K}{\partial \dot{\varepsilon}^p_{ij}} d\dot{\varepsilon}^p_{ij}\right] \tag{8}$$

Combining equations (3) and (8) and changing the repeated indices in equation (8), for clarity, gives the incremental change in the plastic strain:

$$d\varepsilon^p_{ij} = \frac{1}{C \frac{\partial f}{\partial \sigma_{kl}} \frac{\partial f}{\partial \sigma_{kl}}} \left[\frac{\partial f}{\partial \sigma_{mn}} d\sigma_{mn} - \frac{\partial K}{\partial \dot{\varepsilon}^p_{mn}} d\dot{\varepsilon}^p_{mn}\right] \frac{\partial f}{\partial \sigma_{ij}} \tag{9}$$

Consider now the elastic stress-strain relation for incremental changes:

$$d\sigma_{ij} = E_{ijkl}(d\varepsilon_{kl} - d\varepsilon^p_{kl}) \tag{10}$$

where E_{ijkl} represents elastic material properties[2] matrix and $d\varepsilon_{kl}$ the total strain changes.

Returning to equation (7) and substituting for $d\sigma_{ij}$ from equation (10) and rearranging gives:

$$d\lambda = D[\frac{\partial f}{\partial \sigma_{ij}} E_{ijkl} d\varepsilon_{kl} - \frac{\partial K}{\partial \dot{\varepsilon}^p_{ij}} d\dot{\varepsilon}^p_{ij}] \tag{11}$$

where D is by definition:

$$D = [C \frac{\partial f}{\partial \sigma_{ij}} \frac{\partial f}{\partial \sigma_{ij}} + \frac{\partial f}{\partial \sigma_{ij}} E_{ijkl} \frac{\partial f}{\partial \sigma_{kl}}]^{-1} \tag{12}$$

Substituting equation (11) into equation (10) gives:

$$d\sigma_{ij} = [E_{ijkl} - DE_{ijrs}E_{mnkl} \frac{\partial f}{\partial \sigma_{mn}} \frac{\partial f}{\partial \sigma_{rs}}] \, d\varepsilon_{kl}$$

$$+ DE_{ijrs} \frac{\partial f}{\partial \sigma_{rs}} \frac{\partial K}{\partial \dot{\varepsilon}^{p}_{kl}} \, d\dot{\varepsilon}^{p}_{kl} \tag{13}$$

Using shorthand notation previously introduced for elastic-plastic materials[2] permits writing equation (13) in a short form:

$$d\sigma_{ij} = A_{ijkl} d\varepsilon_{kl} + DE_{ijrs} \frac{\partial f}{\partial \sigma_{rs}} \frac{\partial K}{\partial \dot{\varepsilon}^{p}_{kl}} \, d\dot{\varepsilon}^{p}_{kl} \tag{14}$$

It may be noted that if the strain rate term is neglected on the right hand side of equation (14), then the remaining terms represent the relation between total incremental stress and strain changes for elastic-plastic material used in SANX model. The next step in the development of the rate dependent model is to introduce the effective plastic strain increment defined by:

$$d\varepsilon^{p} = \sqrt{2/3 \, d\varepsilon^{p}_{ij} d\varepsilon^{p}_{ij}} \tag{15}$$

The objective of this will be to use this concept to replace the strain rate term on the right hand side of equation (14). Using flow rule, equation (3), in equation (15) results in:

$$d\varepsilon^{p} = d\lambda \sqrt{2/3 \frac{\partial f}{\partial \sigma_{ij}} \frac{\partial f}{\partial \sigma_{ij}}} \tag{16}$$

Returning to the yield function and the function K, an incremental change in this parameter can now be written as:

$$dK = \frac{\partial K}{\partial \dot{\varepsilon}^{p}_{ij}} d\dot{\varepsilon}^{p}_{ij} = \frac{\partial K}{\partial \dot{\varepsilon}^{p}} \frac{\partial \dot{\varepsilon}^{p}}{\partial \dot{\varepsilon}^{p}_{ij}} d\dot{\varepsilon}^{p}_{ij} \tag{17}$$

But:

$$\frac{\partial \dot{\varepsilon}^{p}}{\partial \dot{\varepsilon}^{p}_{ij}} d\dot{\varepsilon}^{p}_{ij} = d\dot{\varepsilon}^{p} \tag{18}$$

Therefore:

$$\frac{\partial K}{\partial \dot{\varepsilon}^{p}_{ij}} d\dot{\varepsilon}^{p}_{ij} = \frac{\partial K}{\partial \dot{\varepsilon}^{p}} d\dot{\varepsilon}^{p} \tag{19}$$

Returning now to equation (7) and substituting for $d\lambda$ from equation (16) and using equation (19) results in:

$$\frac{\partial f}{\partial \sigma_{ij}} d\sigma_{ij} - C \frac{\partial f}{\partial \sigma_{ij}} \frac{\partial f}{\partial \sigma_{ij}} \cdot \frac{d\varepsilon^p}{\sqrt{2/3 \frac{\partial f}{\partial \sigma_{ij}} \frac{\partial f}{\sigma_{ij}}}} - \frac{\partial K}{\partial \dot{\varepsilon}^p} d\dot{\varepsilon}^p = 0 \tag{20}$$

The second term in equation (20) can be simplified and equation rearranged as follows:

$$\frac{\partial K}{\partial \dot{\varepsilon}^p} d\dot{\varepsilon}^p + 3/2\ C \sqrt{2/3 \frac{\partial f}{\partial \sigma_{ij}} \frac{\partial f}{\partial \sigma_{ij}}}\, d\dot{\varepsilon}^p = \frac{\partial f}{\partial \sigma_{ij}} d\sigma_{ij} \tag{21}$$

Equation (21) can be compared directly to equation (III.5a) of Reference 1, for isotropic materials, with the following substitutions:

$$\frac{\partial K}{\partial \dot{\varepsilon}^p} = 2/3\sigma_y \ \frac{\partial \sigma_y}{\partial \dot{\varepsilon}^p} \tag{22}$$

and

$$\sqrt{2/3 \frac{\partial f}{\partial \sigma_{ij}} \frac{\partial f}{\partial \sigma_{ij}}} = 2/3\sigma_y \tag{23}$$

Before proceeding further with equation (21) it is useful to obtain the expression for rate of change of K. Using equation (2) and differentiating:

$$\frac{\partial K}{\partial \dot{\varepsilon}^p} = 2[1 + b\ln(1 + \frac{\dot{\varepsilon}^p}{\dot{\varepsilon}_o})] \frac{b}{\dot{\varepsilon}_o + \varepsilon^p} \tag{24}$$

Consider now equation (21) and apply it to an interval of loading over which the rate of change of stress is represented by a constant.

General equation (21) has variable coefficients. However, if it is applied to a small interval of loading the coefficients can be assumed to be constant over this interval. Over such interval the stress variation can be approximated by a linear variation with time:

$$d\sigma_{ij} = \dot{\sigma}_{ij} dt \tag{25}$$

where $\dot{\sigma}_{ij}$ are constant rates and time t is measured from the beginning of the interval. Equation (21) can now be reduced to an ordinary differential equation over a small time interval. This is done by substituting:

$$d\dot{\varepsilon}^p = \frac{d\dot{\varepsilon}^p}{dt}\,dt$$

$$d\varepsilon^p = \frac{d\varepsilon^p}{dt}\,dt \tag{26}$$

Using equations (25) and (26) in (21) and cancelling dt:

$$\frac{\partial K}{\partial \dot{\varepsilon}^p}\,\ddot{\varepsilon}^p + 3/2\ C\ \sqrt{2/3\,\frac{\partial f}{\partial \sigma_{ij}}\,\frac{\partial f}{\partial \sigma_{ij}}}\ \dot{\varepsilon}^p = \frac{\partial f}{\partial \sigma_{ij}}\,\dot{\sigma}_{ij} \tag{27}$$

The solution to equation (27) can be shown to be of the following form:

$$\varepsilon^p = At + k_1 + k_2 e^{-\lambda t} \tag{28}$$

where by definition:

$$A = \frac{\partial f}{\partial \sigma_{ij}}\,\dot{\sigma}_{ij} \Bigg/ \left(3/2\ C\ \sqrt{2/3\,\frac{\partial f}{\partial \sigma_{ij}}\,\frac{\partial f}{\partial \sigma_{ij}}}\right)$$

$$\lambda = 3/2\ C\ \sqrt{2/3\,\frac{\partial f}{\partial \sigma_{ij}}\,\frac{\partial f}{\partial \sigma_{ij}}} \Bigg/ \frac{\partial K}{\partial \dot{\varepsilon}^p} \tag{29}$$

and k_1 and k_2 are unknown constants. Time t is measured from the start of the interval. The constants k_1 and k_2 are evaluated from the conditions at the start of the interval:

at $t = 0$

$$\varepsilon^p = \varepsilon^p_o$$

$$\dot{\varepsilon}^p = \dot{\varepsilon}^p_0 \tag{30}$$

Using equations (30) to evaluate k_1 and k_2 gives:

$$k_1 = \varepsilon^p_o - \frac{1}{\lambda}\,(A - \dot{\varepsilon}^p_o)$$

$$k_2 = \frac{1}{\lambda}\,(A - \dot{\varepsilon}^p_o) \tag{31}$$

Substituting into equation (28) for k_1 and k_2 results:

$$\varepsilon^p = At + \varepsilon^p_o - \frac{1}{\lambda}\,(A - \dot{\varepsilon}^p_o)(1 - e^{-\lambda t}) \tag{32}$$

Differentiating equation (32) gives the rate of change:

$$\dot{\varepsilon}^p = A - (A - \dot{\varepsilon}^p_o)e^{-\lambda t} \tag{33}$$

Consider now a time interval t=0 to t=Δt and use equation (33) to obtain the change of the effective plastic strain rate:

$$\begin{aligned} d\dot{\varepsilon}^p &= \dot{\varepsilon}^p - \dot{\varepsilon}^p_o \\ &= (A - \dot{\varepsilon}^p_o)(1 - e^{-\lambda\Delta t}) \end{aligned} \tag{34}$$

Returning to the incremental stress-strain relation and substituting first for the rate term from equation (19) and then expressing $d\dot{\varepsilon}^p$ from equation (34) gives the following:

$$\begin{aligned} d\sigma_{ij} &= A_{ijkl}d\varepsilon_{kl} \\ &+ DE_{ijrs}\frac{\partial f}{\partial\sigma_{rs}}\frac{\partial K}{\partial\dot{\varepsilon}^p}(A - \dot{\varepsilon}^p_o)(1 - e^{-\lambda\Delta t}) \end{aligned} \tag{35}$$

Equation (35) is now a suitable incremental relation over a load time step Δt which gives the change in stress in terms of change in total strain and in terms of parameters which can be calculated from previous time step. The second term on the right hand side of equation (35) represents the rate effects and, in the finite element model, it will contribute to the body force.

III. NUMERICAL CALCULATIONS

The analytical development of the previous section has been incorporated into the elastic-plastic version of the SANX computer code.[3] The basic arrangement of the SANX code has been retained. The main changes to the program involve changes in the Subroutine ELPLSS which assembles the incremental plastic stress-strain relations. In the new version the incremental stress-strain relations are based on the equation (35). The basic input procedure for the new SANX is the same as the original code except for the first input card. This card has been modified to input the rate dependent material parameters b, $\dot{\varepsilon}_o$ defined in equation (2), and the time interval Δt needed for the time dependent incremental solution.

The first input card in the original elastic-plastic SANX was:

Card 1 (Original)

Format (2I10)

Columns	1-10	NTOTS Number of segments (8 maximum)
	11-20	NOLINC Number of load increments

The new input card is:

Card 1 (New)

Format (2I10,3E12.6)

Columns	1-10	NTOTS
	11-20	NOLINC
	21-32	DELTIM Time increment Δt
	33-44	BVR Material parameter b
	45-56	EVR Material parameter $\dot{\varepsilon}_o$

In order to check the new program constant stress rate was applied to sample examples which simulates uniaxial loading and the results were compared to those obtained from uniaxial solution of Reference 1. The uniaxial analysis of Reference 1 is in two parts. The first part is an incremental uniaxial solution and the second is an exact solution for constant stress or strain rate loading. The incremental solution of Reference 1 was first compared to the exact solution and it was found that modifications were necessary to the incremental solution to make it agree with the exact formulation. The comparison of the results from the three-dimensional SANX program are made to the modified incremental, uniaxial formulation.

The first comparison was made between the uniaxial incremental solution and the uniaxial exact solution from Reference 1. The purpose of this comparison was to establish the effect on the accuracy of the size of the load steps at various stress rates. Figure 1 shows these results where the incremental and the exact solutions are shown for a wide range of stress rates. The results are presented both in Metric and British units. The Metric units are given in parentheses directly under the corresponding British units. Figure 1 presents results for two load steps of $2x10^3$ psi (13.7 GPa) and $8x10^3$ psi (55.1 GPa). The time step Δt was adjusted to give the desired stress rate. These results are for the following material parameters:

rate-dependent yield parameters;

$$b = 3.67 \times 10^{-2}$$
$$\dot{\varepsilon}_o = 3.0 \times 10^{-2}$$

elastic modulus;

$$E = 16.8 \times 10^6 \text{ psi } (115.7 \text{ GPa})$$

strain hardening parameter;

$$C = 0.259 \times 10^6$$

yield stress;

$$\sigma_y = 133 \times 10^3 \text{ psi } (0.916 \text{ GPa})$$

Comparing solutions in Figure 1 it can be seen that relatively good agreement exists between exact and incremental solutions. This is especially true for the smaller load step of $2x10^3$ psi (13.7 GPa). It is expected that smaller load steps will give more accurate results.

The next comparison involved using the new three-dimensional computer program to analyze a uniaxial situation composed of a cylindrical body subject to axial load. The results are compared to the exact uniaxial solution of Reference 1. These results are presented in Figure 2 for the two different load step sizes used in Figure 1. As in Figure 1, the results are presented in two different systems of units. It is expected that the results in Figure 2 should duplicate results in Figure 1 if the three-dimensional code is working properly. It can be seen that the results between uniaxial incremental solution and the finite element program are almost identical.

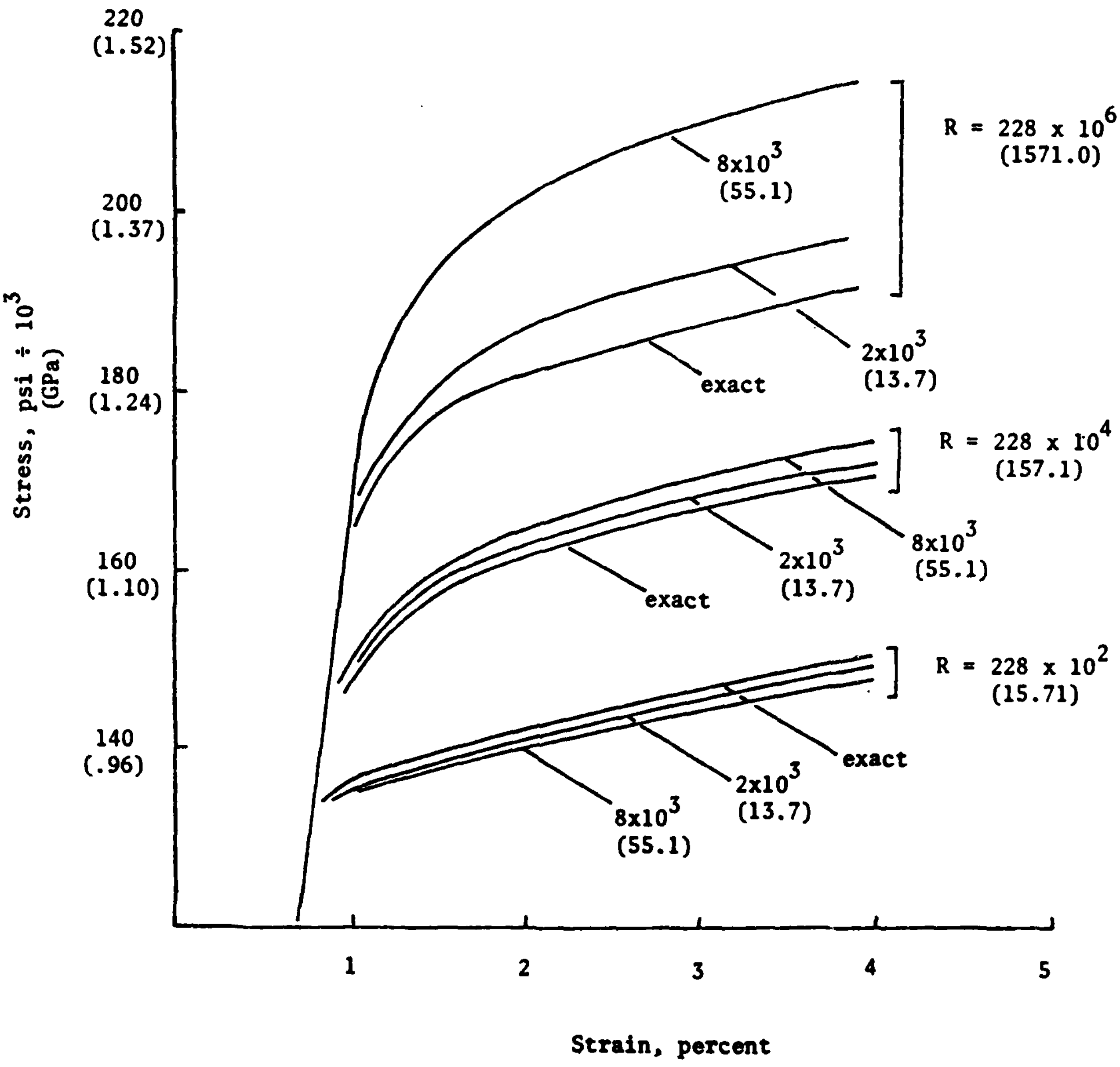

Figure 1. Comparison of uniaxial incremental and exact solutions for different stress rates and different load steps.

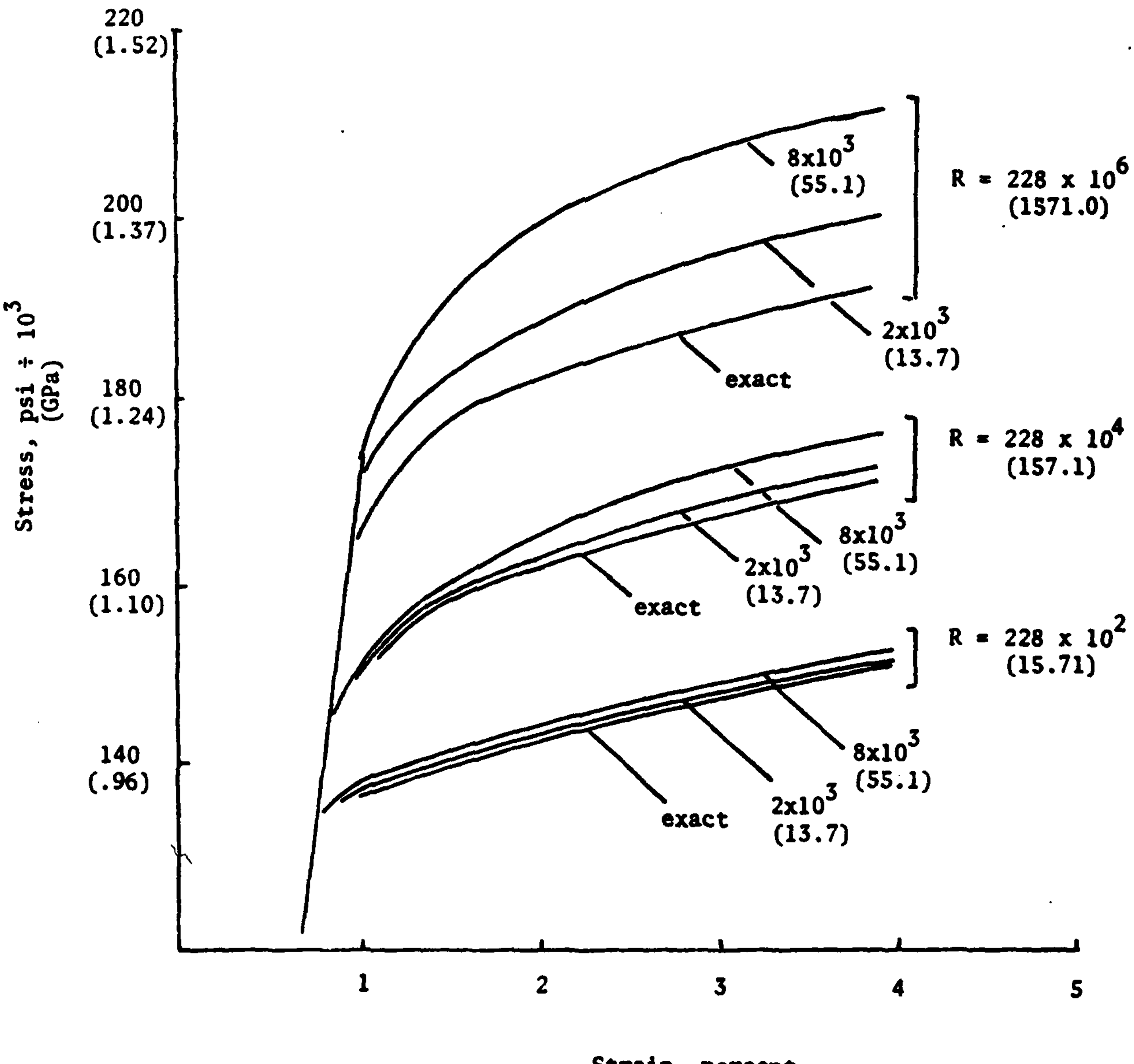

Figure 2. Comparison of three-dimensional incremental solution and exact uniaxial solution for different stress rates and load steps.

REFERENCES

1. W.H. Drysdale, "A Theory of Rate Dependent Plasticity," Ballistic Research Laboratory Report, APG, MD (Forthcoming).

2. A.R. Zak, J.N. Craddock and W.H. Drysdale, "An Elastic-Plastic Analysis of Non-Axisymmetric Structures," International Journal of Computers and Structures, vol. 10, pp. 841-846, 1979.

3. J.N. Craddock and A.R. Zak, "An Approximate Finite Element Method of Stress Analysis of Non-Axisymmetric Bodies with Elastic-Plastic Materials," Technical Rept. UILU-ENG 79 0501, Aeronautical and Astronautical Engineering Dept., University of Illinois, Urbana, March 1979.

APPENDIX A

Computer Listing for the Program SANXVR for the Analysis of Nonaxisymmetric Configuration with Rate Dependent Yield Criterion

```
      PROGRAM SANXVR(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE1,
     1 TAPE2,TAPE3,TAPE15,
     2TAPE21,TAPE25,TAPE26)
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     BRLESC FINITE ELEMENT STRESS ANALYSIS OF AXISYMMETRIC,
C     PLANE STRAIN, AND PLANE STRESS SOLIDS WITH ORTHOTROPIC,
C     TEMPERATURE-DEPENDENT MATERIAL PROPERTIES
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      INTEGER CODE
      COMMON/VISC/EPSDN(12,10,8),SIGVP(6),DEPSR(6,10,8),DELTIM
      COMMON/RATE/DKPR,SIGPR,BVR,EVR,PSRATE( 10,8),NRATE
       COMMON/INCR/NOLINC,NOL,INERT,NUMMAT,SIGTOT(12,  4,8)
     1 ,EPSTOT(12,  4,8)
       COMMON/PLAS/ALFA(6,  4,8),SIGYLD(7,6,8),IFGPL(  4,8)
       COMMON/BOCON/NRDF,NREQ(18),URES(18)
      COMMON/NPDATA/R(10  ),CODE(10  ),XR(10  ),Z(10  ),XZ(10  ),
     1NPNUM( 4,  8),T(10  ),XT(10  )
      COMMON/ARG/RRR(5),ZZZ(5),RR(4),ZZ(4),S(15,15),P(15),TT(6),
     1H(6,15),CRZ(6,6),XI(10),ANGLE(4),SIG(18),EPS(18),N
      COMMON/ELDATA/BETA(10  ),EPR(10  ),PR(4  ),SH(4  ),IX(8   ,5),
     1IP(4  ),JP(4  ),IS(4  ),JS(4  ),ALPHA(10  ),IT(4  ),JT(4  ),
     2ST(4  )
      COMMON/BASIC/ACELZ,ANGVEL,ANGACC,TREF,VOL,NUMNP,NUMEL,NUMPC,NUMSC,
     1NUMST
      COMMON/NXMESH/THETAN(8),NPC(8,8)
      COMMON/ANS1/NUMELS(8),NUMNPS(8)
      COMMON/NXDATA/NTP,NTS,NTOTS,GTS1G(24,24,8)
      COMMON/NONAXI/S1(30,30),P1(30),THETA,BS1(6,30)
      COMMON/SOLVE/X(888),Y(888),TEM(888),NUMTC,MBAND
      COMMON/TD/IMIN(100),IMAX(100),JMIN(25),JMAX(25),MAXI,MAXJ,NMTL,NBC
      COMMON/CONVRG/IDONE
      COMMON/PLANE/NPP
      COMMON/RESULT/BS(6,15),D(6,6),C(6,6),AR,BB(6,9),CNS(6,6)
      COMMON/MATP/RO(6),E(12,16,6),EE(16),AOFTS(6)
      COMMON/NXSOLV/SKG(36 ,24),FTG(132),FTOT(132),ITOT
      DIMENSION TITLE(20)
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     READ AND WRITE CONTROL INFORMATION
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      READ(5,3000) NTOTS,NOLINC,DELTIM,BVR,EVR
       WRITE(6,3017) BVR,EVR
3017   FORMAT(1H ," BVR = ",E12.4," EVR = ",E12.4)
      DO 150 I=1,NTOTS
  150 READ(5,3001) THETAN(I)
      DO 152  I= 1,NTOTS
  152 READ(5,3002) (NPC(I,J),J=1,8)
 3000 FORMAT(2I10,3E12.6)
 3001 FORMAT(F10.5,I10)
 3002 FORMAT(8I10)
       REWIND 15
       REWIND 26
       REWIND 21
       REWIND 25
       WRITE(6,3010)
 3010 FORMAT("1","SEGMENT DATA FOR NONAXISYMMETRIC PROBLEM")
       WRITE(6,3011) NTOTS ,NOLINC ,DELTIM
 3011 FORMAT(" "," NUMBER OF TOTAL SEGMENTS      =",I5,//,
     2           " NUMBER OF LOAD INCREMENTS =",I5,//,
     3        "    TIME INCREMENT =",E15.8)
```

```
      DO 153 I=1,NTOTS
      WRITE(6,3012) I,THETAN(I)
 3012 FORMAT(" ",///," SEGMENT TYPE =",I5/,"     THETA = ",F10.5)
  153 CONTINUE
      DO 154  I=1,NTOTS
  154 WRITE(6,3014)I,(NPC(I,J),J=1,8)
 3014 FORMAT("  ","CONNECTING NODES FOR SEGMENT",I5," ARE",8I5)
      DO 910 NOL=1,NOLINC
      WRITE(6,2030) NOL
      REWIND 15
      DO 950 NTP = 1,NTOTS
      THETA= THETAN(NTP)      /57.295780
      IF(NOL.NE.1)GO TO 525
   50 READ(5,1000 )TITLE,NNLA,NUMTC,NUMMAT,NUMPC,NUMSC,NUMST,TREF
     1,INERT,NLINC,INCI,INCF,IPLOT
      WRITE(6,2000)TITLE,NNLA,NUMTC,NUMMAT,NUMPC,NUMSC,NUMST,TREF,INERT,
     1NLINC
      WRITE(15)NUMTC,NUMMAT,NUMPC,NUMSC,TREF,INERT,INCI,INCF
      NPP=0
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     GENERATE FINITE ELEMENT MESH
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
  100 CALL MESH
      DO 155 I=1,NUMEL
      IFGPL(I,NTP)=0
      PSRATE(I,NTP)=0.0
      DO 155 J=1,12
      SIGTOT(J,I,NTP)=0.0
      EPSTOT(J,I,NTP)=0.0
      ALFA(J,I,NTP)=0.0
      EPSDN(J,I,NTP)=0.0
  155 CONTINUE
      WRITE(15)(R(I),I=1,NUMNP)
      WRITE(15)(Z(I),I=1,NUMNP)
      NUMELS(NTP) = NUMEL
      NUMNPS(NTP) = NUMNP
      IF (IPLOT.EQ.1) CALL MPLOT
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     READ AND WRITE TEMPERATURE DATA
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
  103 IF(NUMTC.EQ.0) GO TO 440
      IF(NUMTC.GT.0) READ(5,1001) (X(I),Y(I),TEM(I),I=1,NUMTC)
      IF(NUMTC.EQ.-2) CALL TEM2(NUMNP)
      IF(NUMTC.EQ.-2) GO TO 440
      MPRINT=0
      DO 210 I=1,NUMTC
      IF(MPRINT.NE.0) GO TO 200
      WRITE(6,2001)
      MPRINT=59
  200 MPRINT=MPRINT-1
  210 WRITE(6,2002) X(I),Y(I),TEM(I)
      MPRINT=0
      DO 230 N=1,NUMNP
      IF(MPRINT.NE.0) GO TO 220
      WRITE(6,2003)
      MPRINT=59
  220 MPRINT=MPRINT-1
      CALL TEMP(R(N),Z(N),T(N))
  230 WRITE(6,2004) N,R(N),Z(N),T(N)
  440 MPRINT=0
```

```
      DO 460 N=1,NUMEL
      IF(MPRINT.NE.0) GO TO 450
      WRITE(6,2008)
      MPRINT=59
  450 MPRINT=MPRINT-1
      II=IX(N,1)
      JJ=IX(N,2)
      KK=IX(N,3)
      LL=IX(N,4)
C
C     TEM IS TEMPORARY STORAGE FOR ELEMENT TEMPERATURES
C
      TEM(N)=(T(II)+T(JJ)+T(KK)+T(LL))/4.00
  460 WRITE(6,2009) N,(IX(N,I),I=1,5),BETA(N),ALPHA(N),TEM(N)
       WRITE(15)((IX(I,J),J=1,5),I=1,NUMEL)
       WRITE(15)(BETA (I),I=1,NUMEL)
       WRITE(15)(ALPHA(I),I=1,NUMEL)
       WRITE(15)(TEM  (I),I=1,NUMEL)
      DO 470 K=1,NUMEL
  470 T(K)=TEM(K)
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     READ AND WRITE MATERIAL PROPERTIES
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
  500 CONTINUE
      DO 510 M=1,NUMMAT
      READ(5,1004)  MTYPE,(NT,RO(MTYPE),AOFTS(MTYPE))
      WRITE(6,2010) MTYPE,NT,RO(MTYPE)
      READ(5,1005)((E(I,J,MTYPE),J=1,14),I=1,NT)
       READ(5,1005)(SIGYLD(I,MTYPE,NTP),I=1,7)
      IF(AOFTS(MTYPE).NE.1.) WRITE(6,2011)((E(I,J,MTYPE),J=1,13),I=1,NT)
      IF(AOFTS(MTYPE).EQ.1.) WRITE(6,2012)((E(I,J,MTYPE),J=1,13),I=1,NT)
       WRITE(6,3015)(SIGYLD(I,MTYPE,NTP),I=1,7)
 3015  FORMAT(1H ,"YIELD STRESSES ARE :",/
     11H ,"Y11 = ",E15.7/
     21H ,"Y22 = ",E15.7/
     31H ,"Y33 = ",E15.7/
     41H ,"Y12 = ",E15.7/
     51H ,"Y13 = ",E15.7/
     61H ,"Y13 = ",E15.7/
     71H ,"  C = ",E15.7)
         WRITE(15)MTYPE,NT, RO(MTYPE)
        WRITE(15)((E(I,J,MTYPE),J=1,14),I=1,NT)
      DO 510 I=NT,12
      DO 510 J=1,16
  510 E(I,J,MTYPE)=E(NT,J,MTYPE)
       GO TO 526
  525  CALL DATA
  526  CONTINUE
      DO 900 NL=1,NLINC
      ACELZ=0.00
      ANGVEL=0.00
      ANGACC=0.00
      IF(INERT .EQ. 0) GO TO 511
      IF(NL .NE. 1 .AND. INCI .EQ. 0) GO TO 511
C*********************************************************************
C     READ AND WRITE DYNAMIC FORCES
C*********************************************************************
      READ(5,1030) ACELZ, ANGVEL, ANGACC
      WRITE(6,2031) ACELZ, ANGVEL, ANGACC
  511 CONTINUE
```

```
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     READ AND WRITE PRESSURE AND SHEAR BOUNDARY CONDITIONS
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      IF(NL .NE. 1 .AND. INCF .EQ. 0) GO TO 700
  600 IF(NUMPC.EQ.0) GO TO 630
      MPRINT=0
      DO 620 L=1,NUMPC
      IF(MPRINT.NE.0) GO TO 610
      WRITE(6,2013)
      MPRINT=58
  610 MPRINT=MPRINT-1
      READ(5,1006)  IP(L),JP(L),PR(L)
  620 WRITE(6,2014) IP(L),JP(L),PR(L)
  630 IF(NUMSC.EQ.0) GO TO 701
      MPRINT=0
      DO 650 L=1,NUMSC
      IF(MPRINT.NE.0) GO TO 640
      WRITE(6,2015)
      MPRINT=58
  640 MPRINT=MPRINT-1
      READ(5,1006)  IS(L),JS(L),SH(L)
  650 WRITE(6,2014) IS(L),JS(L),SH(L)
  701 IF(NUMST.EQ.0) GO TO 700
      MPRINT=0
      DO 680 L=1,NUMST
      IF(MPRINT.NE.0) GO TO 670
      WRITE(6,2025)
      MPRINT=58
  670 MPRINT=MPRINT-1
      READ(5,1006) IT(L),JT(L),ST(L)
  680 WRITE(6,2014)IT(L),JT(L),ST(L)
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     DETERMINE BANDWIDTH, INITIALIZE ELASTIC-PLASTIC RATIO,
C     AND CONVERT BETA FROM DEGREES TO RADIANS
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
  700 J=0
      DO 710 N=1,NUMEL
      IX(N,5)=IABS(IX(N,5))
      DO 710 I=1,4
      DO 710 L=1,4
      KK=IABS(IX(N,I)-IX(N,L))
      IF(KK.GE.J) J=KK
  710 CONTINUE
      MBAND=3*J+3
      IF(NL.GT.1) GO TO 721
      DO 720 N=1,NUMEL
      EPR(N)=1.
      ALPHA(N)=ALPHA(N)/57.295780
  720 BETA(N)=BETA(N)/57.295780
  721 CONTINUE
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     SOLVE NONLINEAR PROBLEM BY SUCCESSIVE APPROXIMATIONS
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      DO 800 NNN=1,NNLA
C
C     FORM STIFFNESS MATRIX
C
      CALL STIFF
C
C     SOLVE FOR DISPLACEMENTS
```

```
C
      CALL SOLV
C
C     COMPUTE STRESSES
C
C
      CALL STRESS
      CALL STORE
      IF(IDONE.NE.1) GO TO 800
  799 NITER=NNN
      IF(IDONE.EQ.1) GO TO 810
  800 CONTINUE
  810 IF(IDONE.EQ.1) WRITE(6,2016) NITER
      IF(IDONE.NE.1) WRITE(6,2017) NITER
  900 CONTINUE
  950 CONTINUE
      ITOT=24+12*(NTOTS-1)                                              NEWDYN

      IF(NOL.NE.1)  GO TO 88                                            NEWDYN

C*********************************************************************  NEWDYN

C     INITIALIZE PREVIOUS HISTORY TOTAL DISPLACEMENTS                   NEWDYN

C*********************************************************************  NEWDYN

      DO  89  I=1,ITOT                                                  NEWDYN

      FTOT(I)=0.00                                                      NEWDYN

   89 CONTINUE                                                          NEWDYN

   88 CONTINUE                                                          NEWDYN

       CALL ASEMBL
       CALL ANSWER
  910 CONTINUE
 1000 FORMAT(20A4/6I5,F5.0,5I5)
 1001 FORMAT(3F10.0)
 1004 FORMAT (2I5,2F10.0)
 1005 FORMAT(7F10.0)
 1006 FORMAT (2I5,F10.0)
 1030 FORMAT(3F10.0)
 2000 FORMAT (2H1 ,20A4/
     1 33H0   NUMBER OF APPROXIMATIONS------I4/
     2 33H0   NUMBER OF TEMPERATURE CARDS---I4/
     3 33H0   NUMBER OF MATERIALS-----------I4/
     4 33H0   NUMBER OF PRESSURE CARDS------I4/
     5 33H0   NUMBER OF SHEAR CARDS---------I4/
     6 33H0   NUMBER OF TORSION CARDS-------I4/
     7 33H0   REFERENCE TEMPERATURE---------E12.4/
     8 33H0   NUMBER OF INERTIA CARDS-------I4/
     9 33H0   NUMBER OF LOAD INCREMENTS-----I4/)
 2001 FORMAT (1H1,13X,1HR,14X,1HZ,14X,1HT)
 2002 FORMAT (3F15.3)
 2003 FORMAT (35H1    N       R          Z             T)
 2004 FORMAT (I5,2F10.4,F10.0)
 2008 FORMAT (74H1  EL    I    J    K   L     MATERIAL    ANGLE BETA    ANGLE A
     1LPHA     TEMPERATURE)
 2009 FORMAT (I5,4I4,I8,F11.1,2F13.3)
 2010 FORMAT (1H1,"MATERIAL IDENTIFICATION NUMBER =",I2/
```

```
    11H ,"NO. OF MATERIAL TEMPERATURE CARDS =",I2/
    21H ,"MASS DENSITY =",E15.7)
 2011 FORMAT (1H ,"TEMPERATURE =",E15.7/
    11H ,"MODULUS OF ELASTICITY-EN =",E15.7/
    21H ,"MODULUS OF ELASTICITY-ES =",E15.7/
    31H ,"MODULUS OF ELASTICITY-ET =",E15.7/
    41H ,"POISSON RATIO-NUNS =",E15.7/
    51H ,"POISSON RATIO-NUNT =",E15.7/
    61H ,"POISSON RATIO-NUST =",E15.7/
    71H ,"SHEAR MODULUS-GNS =",E15.7/
    81H ,"SHEAR MODULUS-GST =",E15.7/
    91H ,"SHEAR MODULUS-GTN =",E15.7/
    11H ,"COEFFICIENT OF THERMAL EXPANSION-AN =",E15.7/
    21H ,"COEFFICIENT OF THERMAL EXPANSION-AS =",E15.7/
    31H ,"COEFFICIENT OF THERMAL EXPANSION-AT =",E15.7/)
 2012 FORMAT (1H ,"TEMPERATURE =",E15.7/
    11H ,"MODULUS OF ELASTICITY-EN =",E15.7/
    21H ,"MODULUS OF ELASTICITY-ES =",E15.7/
    31H ,"MODULUS OF ELASTICITY-ET =",E15.7/
    41H ,"POISSON RATIO-NUNS =",E15.7/
    51H ,"POISSON RATIO-NUNT =",E15.7/
    61H ,"POISSON RATIO-NUST =",E15.7/
    71H ,"SHEAR MODULUS-GNS =",E15.7/
    81H ,"SHEAR MODULUS-GST =",E15.7/
    91H ,"SHEAR MODULUS-GTN =",E15.7/
    11H ,"FREE THERMAL STRAIN-FN =",E15.7/
    21H ,"FREE THERMAL STRAIN-FS =",E15.7/
    31H ,"FREE THERMAL STRAIN-FT =",E15.7/)
 2013 FORMAT (30H  PRESSURE BOUNDARY CONDITIONS/20H    I    J  PRESSURE)
 2014 FORMAT (2I5,F10.1)
 2015 FORMAT (27H  SHEAR BOUNDARY CONDITIONS/17H    I    J  SHEAR)
 2016 FORMAT (26H  THE SYSTEM CONVERGED IN I2,11H ITERATIONS)
 2017 FORMAT (33H  THE SYSTEM DID NOT CONVERGE IN I2,11H ITERATIONS)
 2024 FORMAT (43H0 THE AXISYMMETRIC OPTION HAS BEEN SELECTED)
 2025 FORMAT(30H   TORSION BOUNDARY CONDITIONS/17H    I    J  SHEAR)
 2030 FORMAT(1H ,45X,"************  LOAD STEP ************ =",I4)
 2031 FORMAT(1H0 ,"AXIAL ACCELERATION  =",E12.4/
    11H0 ,"ANGULAR VELOCITY    =",E12.4/
    21H0 ,"ANGULAR ACCELERATION=",E12.4)
  920 STOP
      END
      SUBROUTINE ANGLE (R,Z,RC,ZC,ANG)
C     FIND ANGLE OF INCLINATION BETWEEN 0 AND 2*PI
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      PI=3.1415927
      D1=(Z-ZC)
      D2=(R-RC)
      IF(ABS(R-RC).GT.1.E-8) GO TO 100
      ANG=PI/2.
      IF(D1.GT.1.E-8) RETURN
      ANG=-ANG
      RETURN
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     ALLOW CIRCLE TO CROSS AXIS
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
  100 ANG=ATAN2(D1,D2)
      RETURN
      END
       SUBROUTINE ANSWER
      INTEGER CODE
```

```
      COMMON/VISC/EPSDN(12,10,8),SIGVP(6),DEPSR(6,10,8),DELTIM
       COMMON/RESULT/BS(6,15),D(6,6),C(6,6),AR,BB(6,9),CNS(6,6)
       COMMON/PLAS/ALFA(6,   4,8),SIGYLD(7,6,8),IFGPL(   4,8)
       COMMON/INCR/NOLINC,NOL,INERT,NUMMAT,SIGTOT(12,   4,8)
     1 , EPSTOT(12,   4,8)
      COMMON/ELDATA/BETA(10   ),EPR(10   ),PR(4   ),SH(4   ),IX(8    ,5),
     1IP(4   ),JP(4   ),IS(4   ),JS(4   ),ALPHA(10   ),IT(4   ),JT(4   ),
     2ST(4   )
      COMMON/ARG/RRR(5),ZZZ(5),RR(4),ZZ(4),S(15,15),P(15),TT(6),
     1H(6,15),CRZ(6,6),XI(10),ANGLE(4),SIG(18),EPS(18),N
      COMMON/NXSOLV/SKG(36  ,24),FTG(132),FTOT(132),ITOT
      COMMON/ANS2/ UT1(24), G(24,24), GR1(24,24),DUMM(24,24)
      COMMON/ANS1/NUMELS(8),NUMNPS(8)
      COMMON/NONAXI/S1(30,30),P1(30),THETA,BS1(6,30)
      COMMON/NXDATA/NTP,NTS,NTOTS,GTS1G(24,24,8)
      COMMON/NXMESH/THETAN(8),NPC(8,8)
      COMMON/ARG1/SIG1(18),EPS1(18),DEPSP(12),CEPSP(6,6)
      COMMON/SOLVE/B(  72),A(  72,36),NUMBLK,MBAND
        DIMENSION UT(24),UC1(24),UC(24),R1(24,24)
       REWIND 25
      REWIND 26
      REWIND 21
         KOLD=1
       DO 100 K=1,NTOTS
       NS=K
       KNEW=K
      NUMNP = NUMNPS(K)
       NUMNP3 = 3*NUMNP
       NUMEL = NUMELS(K)
       K20 = 21
      READ(26) (B(I),I=1,NUMNP3)
      READ(26) ((IX(I,J),J=1,5),I=1,NUMEL)
       WRITE(6,1200) K
       READ(25)((R1(I,J),J=1,24),I=1,24)
       DO 110 KK=1,4
       NP1 = NPC(NS,KK)
       NP2 = NPC(NS,KK+4)
       DO 110 I=1,3
      UC(3*(KK-1)+I) = B(3*NP1-3+I)
       UC(3*(KK-1)+I+12) = B(3*NP2-3+I)
  110  CONTINUE
      DO 115 KK=1,24
  115  UT(KK) = FTG(KK+(NS-1)*12)
      WRITE(6,900)
  900  FORMAT(" "," EL    SIGMAR    SIGMAZ    SIGMAC    SIGMARZ  SIGMAZC"
     1   ," SIGMACR    SIGMAN    SIGMAS    SIGMAT    SIGMANS",
     2  "    SIGMATN",/"        EPSR       EPSZ       EPSC       EPSRZ     ",
     3    "EPSZC      EPSCR       EPSN      EPSS      EPST      EPSNS      ",
     4   " EPSST      EPSTN")
        IF(KOLD.EQ.KNEW) REWIND 21
        IF(KOLD.NE.KNEW) KOLD=KNEW
       DO 120 N=1,NUMEL
       MTYPE=IABS(IX( N,5))
       READ(K20)((CRZ(I,J),J=1,6),I=1,6)
       READ(K20)((BS1(I,J),J=1,30),I=1,6)
       READ(K20)((   G(I,J),J=1,24),I=1,24)
       READ(K20)((CEPSP(I,J),J=1,6),I=1,6)
       READ(K20)((CNS(I,J),J=1,6),I=1,6)
       READ(K20)((D(I,J),J=1,6),I=1,6)
       READ(K20)((C(I,J),J=1,6),I=1,6)
```

```
      DO 125 I=1,24
     DO 125 J=1,24
        GR1(I,J) = 0.00
      DO 125 M=1,24
125  GR1(I,J) = GR1(I,J) + G(I,M)*R1(M,J)
      DO 126 I=1,24
     UC1(I) =0.00
     UT1(I) =0.00
      DO 126 J=1,24
      UC1(I) = UC1(I) + GR1(I,J)*UC(J)
126  UT1(I) = UT1(I) + GR1(I,J)*UT(J)
      DO 130 I=1,4
     II=3*I
      JJ=3*IX(N,I)
      P1(II-2) = B(JJ-2)
      P1(II-1) = B(JJ-1)
      P1(II   ) = B(JJ   )
      P1(II+10) = B(JJ-2)
      P1(II+11) = B(JJ-1)
      P1(II+12) = B(JJ)
130   CONTINUE
      DO 135 I=1,24
135  P1(I) = P1(I) -UC1(I)+UT1(I)
      DO 136  I=1,3
     P1(I+24)= (P1(I)+P1(I+3)+P1(I+6)+P1(I+9))/4.00
136  P1(I+27) = (P1(I+12)+P1(I+15)+P1(I+18)+P1(I+21))/4.00
      DO 140 I=1,6
      EPS1(I) = 0.00
      DO 140 J=1,30
140  EPS1(I) = EPS1(I)+BS1(I,J)*P1(J)
      DO 143 I=1,6
      EPS1(I+6)=0.0
      DO 143 J=1,6
      DO 143 L=1,6
143   EPS1(I+6)=EPS1(I+6)+D(I,J)*C(J,L)*EPS1(L)
      DO 150 I=1,6
     SIG1(I) = EPSDN(I,N,NS)
     SIG1(I+6)=EPSDN(I+6,N,NS)
      SIGVP(I)=0.0
      DO 150  J=1,6
      SIG1(I)= SIG1(I) +  CRZ(I,J)*EPS1(J)
150   SIG1(I+6)=SIG1(I+6)+CNS(I,J)*EPS1(J+6)
      DO 151 I=1,6
      SIGVP(I)=SIG1(I+6)
151   CONTINUE
     DO 141 J=1,12
141    EPS1(J) = EPS1(J)*100.0
      DO 230 I=1,6
      DEPSP(I)=0.0
230   DEPSP(I+6)=0.0
      IF (IFGPL(N,NS).EQ.0) GO TO 241
      DO 250 I=1,6
      DO 250 J=1,6
250   DEPSP(I+6)=DEPSP(I+6)+CEPSP(I,J)*EPS1(J+6)/100.
      DO 251 I=1,6
251   DEPSP(I+6)=DEPSP(I+6)+DEPSR(I,N,NS)
      D(4,1)=0.5*D(4,1)
      D(4,3)= 0.5*D(4,3)
      D(1,6)=2.0*D(1,6)
      D(2,6)= 2.0*D(2,6)
```

```
      C(1,4)= 2.0*C(1,4)
      C(2,4)= 2.0*C(2,4)
      C(4,1)= 0.5*C(4,1)
      C(4,2)= 0.5*C(4,2)
      DO 160 I=1,6
      DEPSP(I)=0.0
      DO 160 J=1,6
     DO 160 L=1,6
  160 DEPSP(I)=DEPSP(I)+C(J,I)*D(J,L)*DEPSP(L+6)
      WRITE(6,1400)(DEPSP(I),I=1,12)
 1400 FORMAT(" PLASTIC STRAINS"/2X, 12E10.4)
C     DO 233  I=1,6
C     EPSDN(I,N,NS)=DEPSP(I+6)/DELTIM
C 233 CONTINUE
  241 CONTINUE
      DO 240  I=1,12
      SIGTOT(I,N,NS)=SIGTOT(I,N,NS)+SIG1(I)
  240 EPSTOT(I,N,NS)=EPSTOT(I,N,NS)+EPS1(I)
      WRITE(6,1000) N,(SIGTOT(I,N,NS),I=1,12)
      WRITE(6,1111)
 1111 FORMAT(" ","SIGVP  ")
      WRITE(6,1000) N,(SIGVP(I),I=1,6)
      CALL YIELD(N,NS,MTYPE)
      IF(IFGPL(N,NS).EQ.1)  WRITE(6,1300)N,NS
 1300 FORMAT(" ","ELEMENT",I5,"OF SEGMENT",I5,"HAS YIELDED")
      WRITE(6,1100) (EPSTOT(I,N,NS),I=1,12)
  120 CONTINUE
  100 CONTINUE
      REWIND 21
      REWIND 25
      REWIND 26
 1000 FORMAT(" ",I5,12F9.0)
 1100 FORMAT(" " ,5X,12F9.5)
 1200 FORMAT("1","SEGMENT TYPE",I5,//," ","SEGMENT NUMBER = ",I5)
      RETURN
      END
      SUBROUTINE ASEMBL
      COMMON/INCR/NOLINC,NOL,INERT,NUMMAT,SIGTOT(12,  4,8)
     1 ,EPSTOT(12,  4,8)
      COMMON/BOCON/NRDF,NREQ(18),URES(18)
     COMMON/GLBSEG/FI(24,8),FE(24,8),UC(24,8),SK(24,24,8)
     COMMON/NXDATA/NTP,NTS,NTOTS,GTS1G(24,24,8)
     COMMON/NXSOLV/SKG(36 ,24),FTG(132),FTOT(132),ITOT
     COMMON/ANS2/FC(24),G(24,24),GR1(24,24),DUMM(24,24)
     ITOT= 24 + 12*(NTOTS-1)
      DO 10 I=1,ITOT
      FTG(I) = 0.00
      DO 10 J = 1,24
   10 SKG(I,J) = 0.00
      DO 100 M=1,NTOTS
C ***************************************************************
C   COMBINE FI, FE, AND SK*UC INTO A TOTAL FORCE VECTOR  FC
C ***************************************************************
      DO 55 I=1,24
      FC(I) = 0.00
       DO 55 J=1,24
   55 FC(I) = FC(I) + SK(I,J,M)* UC(J,M)
      DO  60 I=1,24
   60 FC(I) = FC(I) +FE(I,M) -FI(I,M)
C ***************************************************************
```

```
C   NOW FILL GLOBAL FORCE AND STIFFNESS MATRICES
C ***************************************************************
        DO 70 I=1,24
         I1 = I+(M-1)*12
          FTG(I1) = FTG(I1)  + FC(I)
        DO 70 J=I,24
        SKG(I1,J+1-I) = SKG (I1,J+1-I) + SK(I,J,M)
   70   CONTINUE
  100   CONTINUE
        IF (NOL.NE.1) GO TO 80
C  READ THE TOTAL NUMBER OF RESTRAINED DEGREES OF FREEDOM
        READ(5,1200)  NRDF
        WRITE(6,1255) NRDF
C    IMPOSE BOUNDARY CONDITIONS ON RESTRAINED D-O-F
        DO 150  NBC=1,NRDF
C  READ THE EQUATION NUMBER AND THE IMPOSED BOUNDARY CONDITION
        READ(5,1250) NREQ(NBC),URES(NBC)
        WRITE(6,1260)NREQ(NBC),URES(NBC)
  150 CONTINUE
   80   CONTINUE
        DO 160 NBC=1,NRDF
  160   CALL XMODFY(URES(NBC),NREQ(NBC))
 1200   FORMAT(I5)
 1250 FORMAT(I5,F10.0)
 1255 FORMAT(1H1,"NUMBER OF RESTRAINED DEGREES OF FREEDOM =",I10/
     1     " EQUATION NUMBER   VALUE  ")
 1260 FORMAT (" ",5X,I5,5X,F10.2)
      CALL XSOLVE
       WRITE(6,1050)
        WRITE(6,1100)(FTG(I),I=1,ITOT)
      DO 200 I=1,ITOT
 200  FTOT(I)=FTOT(I)+FTG(I)
       WRITE(6,1051)
        WRITE(6,1100)(FTOT(I),I=1,ITOT)
 1050 FORMAT("1","INCREMENTAL DISPLACEMENTS AT CONNECTING NODES"/
     1           18X,2HUR,18X,2HUZ,18X,2HUT)
 1100  FORMAT(" ",3E20.7)
 1051 FORMAT("1","TOTAL DISPLACEMENTS AT CONNECTING NODES"/
     1           18X,2HUR,18X,2HUZ,18X,2HUT)
       RETURN
      END
      SUBROUTINE CIRCLE(ANG1,DELPHI,RSTRT,ZSTRT,RC,ZC,I,J)
      INTEGER CODE
      COMMON/TD/IMIN(100),IMAX(100),JMIN(25),JMAX(25),MAXI,MAXJ,NMTL,NBC
      COMMON/NPDATA/R(10   ),CODE(10   ),XR(10   ),Z(10   ),XZ(10   ),
     1NPNUM( 4,   8),T(10   ),XT(10   )
      DIMENSION AR( 4,   8),AZ( 4,   8)
      EQUIVALENCE (R(1),AR),(Z(1),AZ)
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     FIND INTERSECTION OF LINE AND CIRCLE = NEW R AND Z
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      ANG1=ANG1+DELPHI
      RR=SQRT((RSTRT-RC)**2+(ZSTRT-ZC)**2)
      AR(I,J)=RC+RR*COS(ANG1)
      AZ(I,J)=ZC+RR*SIN(ANG1)
      RETURN
      END
       SUBROUTINE DATA
       INTEGER CODE
      COMMON/INCR/NOLINC,NOL,INERT,NUMMAT,SIGTOT( 12,   4,8)
```

```
     1   ,EPSTOT(12,   4,8)
      COMMON/NPDATA/R(10   ),CODE(10   ),XR(10   ),Z(10   ),XZ(10   ),
     1 NPNUM( 4,   8),T(10   ),XT(10   )
      COMMON/BASIC/ACELZ,ANGVEL,ANGACC,TREF,VOL,NUMNP,NUMEL,NUMPC,NUMSC
     1NUMST
      COMMON/ELDATA/BETA(10   ),EPR(10   ),PR(4   ),SH(4   ),IX(8   ,5),
     1IP(4   ),JP(4   ),IS(4   ),JS(4   ),ALPHA(10   ),IT(4   ),JT(4   ),
     2ST(4   )
       COMMON/NXDATA/NTP,NTS,NTOTS,GTSIG(24,24,8)
      COMMON/MATP/RO(6),E(12,16,6),EE(16),AOFTS(6)
       COMMON/SOLVE/X(888),Y(888),TEM(888),NUMTC,MBAND
       COMMON/TD/IMIN(100),IMAX(100),JMIN(25),JMAX(25),MAXI,
     1   MAXJ,NMTL,NBC
       READ(15)NUMTC,NUMMAT,NUMPC,NUMSC,TREF,INERT,
     1 INCI,INCF
       READ(15)NBC,NMTL
       READ(15)NUMEL,NUMNP
       READ(15)(CODE(I),I=1,NUMNP)
       READ(15)(   XR(I),I=1,NUMNP)
       READ(15)(   XT(I),I=1,NUMNP)
       READ(15)(   XZ(I),I=1,NUMNP)
       READ(15)(    R(I),I=1,NUMNP)
       READ(15)(    Z(I),I=1,NUMNP)
       READ(15)((IX(I,J),J=1,5),I=1,NUMEL)
       READ(15)(BETA(I),I=1,NUMEL)
       READ(15)(ALPHA(I),I=1,NUMEL)
       READ(15)(TEM(I),I=1,NUMEL)
       DO 200 I=1,NUMMAT
       READ(15)MTYPE,NT,RO(MTYPE)
       READ(15)((E(II,J,MTYPE),J=1,14),II=1,NT)
       DO 200 K=NT,12
       DO 200 L=1,6
 200   E(K,L,MTYPE)=E(NT,L,MTYPE)
      RETURN
       END
      SUBROUTINE INTER
      COMMON/ARG/RRR(5),ZZZ(5),RR(4),ZZ(4),S(15,15),P(15),TT(6),
     1H(6,15),CRZ(6,6),XI(10),ANGLE(4),SIG(18),EPS(18),N
      COMMON/PLANE/NPP
      DIMENSION XM(7),R(7),Z(7),XX(9)
      DATA XX/3*.1259391805448,3*.1323941527884,.225,
     1 .696140478028,.410426192314/
      R(7)=(RR(1)+RR(2)+RR(3))/3.0
      Z(7)=(ZZ(1)+ZZ(2)+ZZ(3))/3.0
      DO 100 I=1,3
      J=I+3
      R(I)=XX(8)*RR(I)+(1.00-XX(8))*R(7)
      R(J)=XX(9)*RR(I)+(1.00-XX(9))*R(7)
      Z(I)=XX(8)*ZZ(I)+(1.00-XX(8))*Z(7)
 100  Z(J)=XX(9)*ZZ(I)+(1.00-XX(9))*Z(7)
      DO 200 I=1,7
 200  XM(I)=XX(I)*R(I)
      DO 300 I=1,10
 300  XI(I)=0.00
      AREA=.50*(RR(1)*(ZZ(2)-ZZ(3))+RR(2)*(ZZ(3)-ZZ(1))+RR(3)*(ZZ(1)
     1   -ZZ(2)))
      IF(NPP.NE.0) GO TO 600
      DO 400 I=1,7
      XI(1)=XI(1)+XM(I)
      XI(2)=XI(2)+XM(I)/R(I)
```

```
      XI(3)=XI(3)+XM(I)/(R(I)**2)
      XI(4)=XI(4)+XM(I)*Z(I)/R(I)
      XI(5)=XI(5)+XM(I)*Z(I)/(R(I)**2)
      XI(6)=XI(6)+XM(I)*(Z(I)**2)/(R(I)**2)
      XI(7)=XI(7)+XM(I)*R(I)
      XI(8)=XI(8)+XM(I)*Z(I)
      XI(9)=XI(9)+XM(I)*(R(I)**2)
  400 XI(10)=XI(10)+XM(I)*R(I)*Z(I)
      DO 500 I=1,10
  500 XI(I)=XI(I)*AREA
      RETURN
  600 XI(1)=AREA
      XI(7)=R(7)*AREA
      XI(8)=Z(7)*AREA
      RETURN
      END
      SUBROUTINE MESH
      INTEGER CODE
      DIMENSION AR( 4,   8),AZ( 4,   8),NCODE( 4,   8)
      COMMON/TD/IMIN(100),IMAX(100),JMIN(25),JMAX(25),MAXI,MAXJ,NMTL,NBC
      COMMON/NPDATA/R(10   ),CODE(10   ),XR(10   ),Z(10   ),XZ(10   ),
     1NPNUM( 4,   8),T(10   ),XT(10   )
      COMMON/ELDATA/BETA(10   ),EPR(10   ),PR(4   ),SH(4   ),IX(8   ,5),
     1IP(4   ),JP(4   ),IS(4   ),JS(4   ),ALPHA(10   ),IT(4   ),JT(4   ),
     2ST(4   )
      EQUIVALENCE (R(1),AR),(Z(1),AZ),(IX(1,1),NCODE)
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     MESH CONTROL INFORMATION
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      READ (5,1000) MAXI,MAXJ,NSEG,NBC,NMTL
      WRITE(6,2000) MAXI,MAXJ,NSEG,NBC,NMTL
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     INITIALIZE
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      ISEG=-1
      PI=3.1415927
      DO 110 J=1,8
      DO 100 I=1,4
      NCODE(I,J)=0
      AR(I,J)=0.
      AZ(I,J)=0.
      JMAX(I)=0
  100 JMIN(I)=MAXI
      IMIN(J)=MAXJ
  110 IMAX(J)=0
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     LINE SEGMENT CARDS
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
  150 ISEG=ISEG+1
  159 IF(ISEG.EQ.NSEG) GO TO 400
      READ(5,1001) I1,J1,R1,Z1,I2,J2,R2,Z2,I3,J3,R3,Z3,IPTION
      WRITE(6,2001)I1,J1,R1,Z1,I2,J2,R2,Z2,I3,J3,R3,Z3,IPTION
      IPTION=IPTION+1
      AR(I1,J1)=R1
      AZ(I1,J1)=Z1
      NCODE(I1,J1)=1
      CALL MNIMX(I1,J1)
      GO TO (150,200,200,300,300,200,200), IPTION
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     GENERATE STRAIGHT LINES ON BOUNDARY
```

```
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
200   DI= ABS(FLOAT(I2-I1))
      DJ= ABS(FLOAT(J2-J1))
      AR(I2,J2)=R2
      AZ(I2,J2)=Z2
      NCODE(I2,J2)=1
      CALL MNIMX(I2,J2)
      ISTRT=I1
      ISTP=I2
      JSTRT=J1
      JSTP=J2
      DIFF=MAX1(DI,DJ)
      ITER=DIFF-1.
      IINC=0
      JINC=0
      IF(I2.NE.I1) IINC=(I2-I1)/IABS(I2-I1)
      IF(J2.NE.J1) JINC=(J2-J1)/IABS(J2-J1)
      KAPPA=1
      IF(I2.NE.I1.AND.J2.NE.J1.AND.IPTION.NE.3) KAPPA=2
      IF(KAPPA.EQ.2) DIFF=2.*DIFF
      RINC=(R2-R1)/DIFF
      ZINC=(Z2-Z1)/DIFF
      WRITE(6,2002) DI,DJ,DIFF,RINC,ZINC,ITER,IINC,JINC,KAPPA
C
C     CHECK FOR INPUT ERROR
C
      IF(KAPPA.NE.2.OR.DI.EQ.DJ) GO TO 210
      WRITE(6,2003)
      GO TO 150
C
C     INTERPOLATE
C
  210 I=I1
      J=J1
      WRITE(6,2004)
      DO 230 M=1,ITER
      IF(ITER.EQ.0.AND.IPTION.EQ.2) GO TO 230
      IF(ITER.EQ.0.AND.IPTION.EQ.6) GO TO 230
      IF(ITER.EQ.0.AND.IPTION.EQ.7) GO TO 230
      IF(KAPPA.EQ.2) GO TO 220
      IOLD=I
      I=I+IINC
      JOLD=J
      J=J+JINC
      AR(I,J)=AR(IOLD,JOLD)+RINC
      AZ(I,J)=AZ(IOLD,JOLD)+ZINC
      WRITE(6,2005) I,J,AR(I,J),AZ(I,J)
      CALL MNIMX(I,J)
      NCODE(I,J)=1
      GO TO 230
  220 CONTINUE
      IF(I1.GT.I2.AND.IPTION.EQ.7) GO TO 221
      IF(I1.LT.I2.AND.IPTION.EQ.6) GO TO 221
      IOLD=I
      I=I+IINC
      AR(I,J)=AR(IOLD,J)+RINC
      AZ(I,J)=AZ(IOLD,J)+ZINC
      WRITE(6,2005) I,J,AR(I,J),AZ(I,J)
      NCODE(I,J)=1
      CALL MNIMX(I,J)
```

```
      JOLD=J
      J=J+JINC
      AR(I,J)=AR(I,JOLD)+RINC
      AZ(I,J)=AZ(I,JOLD)+ZINC
      NCODE(I,J)=1
      WRITE(6,2005) I,J,AR(I,J),AZ(I,J)
      CALL MNIMX(I,J)
      GO TO 230
  221 JOLD=J
      J=J+JINC
      AR(I,J)=AR(I,JOLD)+RINC
      AZ(I,J)=AZ(I,JOLD)+ZINC
      NCODE(I,J)=1
      WRITE(6,2005) I,J,AR(I,J),AZ(I,J)
      CALL MNIMX(I,J)
      IOLD=I
      I=I+IINC
      AR(I,J)=AR(IOLD,J)+RINC
      AZ(I,J)=AZ(IOLD,J)+ZINC
      NCODE(I,J)=1
      WRITE(6,2005) I,J,AR(I,J),AZ(I,J)
      CALL MNIMX(I,J)
  230 CONTINUE
      IF(KAPPA.EQ.1) GO TO 150
      IF(I1.GT.I2.AND.IPTION.EQ.7) GO TO 231
      IF(I1.LT.I2.AND.IPTION.EQ.6) GO TO 231
      IOLD=I
      I=I+IINC
      AR(I,J)=AR(IOLD,J)+RINC
      AZ(I,J)=AZ(IOLD,J)+ZINC
      GO TO 232
  231 CONTINUE
      JOLD=J
      J=J+JINC
      AR(I,J)=AR(I,JOLD)+RINC
      AZ(I,J)=AZ(I,JOLD)+ZINC
  232 CONTINUE
      NCODE(I,J)=1
      WRITE(6,2005) I,J,AR(I,J),AZ(I,J)
      CALL MNIMX(I,J)
      GO TO 150
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     GENERATE CIRCULAR ARCS ON BOUNDARY
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
  300 AR(I2,J2)=R2
      AZ(I2,J2)=Z2
      NCODE(I2,J2) = 1
      CALL MNIMX(I2,J2)
      IF(IPTION.EQ.5) GO TO 320
C
C     FIND CENTER OF CIRCLE
C
      AR(I3,J3)=R3
      AZ(I3,J3)=Z3
      NCODE(I3,J3)=1
      CALL MNIMX(I3,J3)
      SLAC=(Z2-Z1)/(R2-R1)
      SLBF=-1./SLAC
      SLCE=(Z3-Z2)/(R3-R2)
      SLDF=-1./SLCE
```

```
C
C     CHECK FOR INPUT ERROR
C
      IF(ABS(SLAC-SLCE).GT..001) GO TO 310
      WRITE(6,2006) R1,Z1,R2,Z2,R3,Z3,SLAC,SLCE
      GO TO 150
  310 R4=R1+(R2-R1)/2.
      Z4=Z1+(Z2-Z1)/2.
      R5=R2+(R3-R2)/2.
      Z5=Z2+(Z3-Z2)/2.
      BBF=Z4-SLBF*R4
      BDF=Z5-SLDF*R5
      RC=(BBF-BDF)/(SLDF-SLBF)
      ZC=SLBF*RC+BBF
      WRITE(6,2007) RC,ZC
      KAPPA=1
      GO TO 330
  320 KAPPA=2
      RC=R3
      ZC=Z3
  330 ISTRT=I1
      ISTP=I2
      JSTRT=J1
      JSTP=J2
      RSTRT=R1
      RSTP=R2
      ZSTRT=Z1
      ZSTP=Z2
  340 CALL ANGLE(RSTRT,ZSTRT,RC,ZC,ANG1)
      CALL ANGLE(RSTP,ZSTP,RC,ZC,ANG2)
      IF(ANG2.LE.ANG1)  ANG2=2.0*PI+ANG2
C
C     FIND ANGULAR INCREMENT
C
      DI= ABS(FLOAT(ISTP-ISTRT))
      DJ= ABS(FLOAT(JSTP-JSTRT))
      IINC=0
      JINC=0
      IF(ISTRT.NE.ISTP) IINC=(ISTP-ISTRT)/IABS(ISTP-ISTRT)
      IF(JSTRT.NE.JSTP) JINC=(JSTP-JSTRT)/IABS(JSTP-JSTRT)
      LAMDA=1
      IF(IINC.NE.0.AND.JINC.NE.0) LAMDA=2
      DIFF=MAX1(DI,DJ)
      ITER=DIFF-1.
      IF(LAMDA.EQ.2) DIFF=2.*DIFF
      DELPHI=(ANG2-ANG1)/DIFF
      WRITE(6,2008) ANG1,ANG2,DIFF,DELPHI
C
C     CHECK FOR INPUT ERROR
C
      IF(LAMDA.NE.2.OR.DI.EQ.DJ) GO TO 350
      WRITE(6,2003)
      GO TO 150
  350 IO=ISTRT
      JO=JSTRT
      WRITE(6,2004)
C
C     INTERPOLATE
C
      NPT=IABS(I2-I1)+IABS(J2-J1)-1
```

```
      DO 380 N=1,ITER
  359 IF(LAMDA.EQ.2) GO TO 360
      I=IO+IINC
      J=JO+JINC
      CALL MNIMX(I,J)
      NCODE(I,J)=1
      CALL CIRCLE(ANG1,DELPHI,RSTRT,ZSTRT,RC,ZC,I,J)
      WRITE(6,2005) I,J,AR(I,J),AZ(I,J)
      GO TO 370
  360 I=IO+IINC
      J=JO
      NCODE(I,J)=1
      CALL MNIMX(I,J)
      CALL CIRCLE(ANG1,DELPHI,RSTRT,ZSTRT,RC,ZC,I,J)
      WRITE(6,2005) I,J,AR(I,J),AZ(I,J)
      J=JO+JINC
      NCODE(I,J)=1
      CALL MNIMX(I,J)
      CALL CIRCLE(ANG1,DELPHI,RSTRT,ZSTRT,RC,ZC,I,J)
      WRITE(6,2005) I,J,AR(I,J),AZ(I,J)
  370 IO=I
  380 JO=J
      IF(LAMDA.NE.2) GO TO 390
      I=IO+IINC
      NCODE(I,J)=1
      CALL MNIMX(I,J)
      CALL CIRCLE(ANG1,DELPHI,RSTRT,ZSTRT,RC,ZC,I,J)
      WRITE(6,2005) I,J,AR(I,J),AZ(I,J)
  390 IF(KAPPA.EQ.2) GO TO 150
      ISTRT=I2
      ISTP=I3
      JSTRT=J2
      JSTP=J3
      RSTRT=R2
      RSTP=R3
      ZSTRT=Z2
      ZSTP=Z3
      KAPPA=2
  399 GO TO 340
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     CALCULATE COORDINATES OF INTERIOR POINTS
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
  400 IF(MAXJ.LE.2) GO TO 430
      J2=MAXJ-1
      DO 420 N=1,500
      RESID=0.
      DO 410 J=2,J2
      I1=IMIN(J)+1
      I2=IMAX(J)-1
      DO 410 I=I1,I2
      IF(NCODE(I,J).EQ.1) GO TO 410
      DR=(AR(I+1,J)+AR(I-1,J)+AR(I,J+1)+AR(I,J-1))/4.-AR(I,J)
      DZ=(AZ(I+1,J)+AZ(I-1,J)+AZ(I,J+1)+AZ(I,J-1))/4.-AZ(I,J)
      RESID=RESID+ABS(DR)+ABS(DZ)
      AR(I,J)=AR(I,J)+1.8*DR
      AZ(I,J)=AZ(I,J)+1.8*DZ
  410 CONTINUE
      IF(N.EQ.1) RES1=RESID
      IF(N.EQ.1.AND.RESID.EQ.0.)GO TO 430
      IF(RESID/RES1.LT.1.E-5) GO TO 430
```

```
  420 CONTINUE
  430 WRITE(6,2009) N
      WRITE(15)NBC,NMTL
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      CALL POINTS
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
 1000 FORMAT (5I5)
 1001 FORMAT (3(2I3,2F8.3),I5)
 2000 FORMAT (30H1  MESH GENERATION INFORMATION//
     1 41H0  MAXIMUM VALUE OF I IN THE MESH--------I3/
     2 41H0  MAXIMUM VALUE OF J IN THE MESH--------I3/
     3 41H0  NUMBER OF LINE SEGMENT CARDS----------I3/
     4 41H0  NUMBER OF BOUNDARY CONDITION CARDS----I3/
     5 41H0  NUMBER OF MATERIAL BLOCK CARDS---------I3///)
 2001 FORMAT (//88H  INPUT    I1   J1     R1       Z1     I2  J2     R2      Z
     12     I3  J3     R3       Z3     IPTION/8X,3(2I4,2F8.4),I6)
 2002 FORMAT (5H  DI=F4.0,5H  DJ=F4.0,7H  DIFF=F4.0,7H  RINC=F8.3,7H  ZI
     1NC=F8.3,7H  ITER=I3,7H  IINC=I3,7H  JINC=I3,8H  KAPPA=I1)
 2003 FORMAT(1X,38H**BAD INPUT--THIS LINE IS NOT DIAGONAL)
 2004 FORMAT (30H    I     J        AR        AZ)
 2005 FORMAT (2I5,2F11.6)
 2006 FORMAT (51H ** BAD INPUT - THESE POINTS DO NOT DEFINE A CIRCLE,/,
     13X,6F12.4,10X,2E20.8)
 2007 FORMAT(19H  CENTER COORDINATE,(F11.6,1X,F11.6,1X))
 2008 FORMAT (7H  ANG1=F9.6,7H  ANG2=F9.6,7H  DIFF=F3.0,9H  DELPHI=F9.6)
 2009 FORMAT (//30H  COORDINATES CALCULATED AFTER I3,11H ITERATIONS)
      RETURN
      END
C
C
C        SUBROUTINE MINV
C
C        PURPOSE
C           INVERT A MATRIX
C
C        USAGE
C           CALL MINV(A,N,D,L,M)
C
C        DESCRIPTION OF PARAMETERS
C           A - INPUT MATRIX, DESTROYED IN COMPUTATION AND REPLACED BY
C               RESULTANT INVERSE.
C           N - ORDER OF MATRIX A
C           D - RESULTANT DETERMINANT
C           L - WORK VECTOR OF LENGTH N
C           M - WORK VECTOR OF LENGTH N
C
C        REMARKS
C           MATRIX A MUST BE A GENERAL MATRIX
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C           THE STANDARD GAUSS-JORDAN METHOD IS USED. THE DETERMINANT
C           IS ALSO CALCULATED. A DETERMINANT OF ZERO INDICATES THAT
C           THE MATRIX IS SINGULAR.
C
C     ..................................................................
C
      SUBROUTINE MINV(A,N,D,L,M)
```

```
      DIMENSION A(1),L(1),M(1)
C
C        ...............................................................
C
C        IF A DOUBLE PRECISION VERSION OF THIS ROUTINE IS DESIRED, THE
C        C IN COLUMN 1 SHOULD BE REMOVED FROM THE DOUBLE PRECISION
C        STATEMENT WHICH FOLLOWS.
C
C     DOUBLE PRECISION A,D,BIGA,HOLD
C
C        THE C MUST ALSO BE REMOVED FROM DOUBLE PRECISION STATEMENTS
C        APPEARING IN OTHER ROUTINES USED IN CONJUNCTION WITH THIS
C        ROUTINE.
C
C        THE DOUBLE PRECISION VERSION OF THIS SUBROUTINE MUST ALSO
C        CONTAIN DOUBLE PRECISION FORTRAN FUNCTIONS.  ABS IN STATEMENT
C        10 MUST BE CHANGED TO DABS.
C
C        ...............................................................
C
C        SEARCH FOR LARGEST ELEMENT
C
      D=1.0
      NK=-N
      DO 80 K=1,N
      NK=NK+N
      L(K)=K
      M(K)=K
      KK=NK+K
      BIGA=A(KK)
      DO 20 J=K,N
      IZ=N*(J-1)
      DO 20 I=K,N
      IJ=IZ+I
   10 IF(ABS(BIGA)-ABS(A(IJ))) 15,20,20
   15 BIGA=A(IJ)
      L(K)=I
      M(K)=J
   20 CONTINUE
C
C        INTERCHANGE ROWS
C
      J=L(K)
      IF(J-K) 35,35,25
   25 KI=K-N
      DO 30 I=1,N
      KI=KI+N
      HOLD=-A(KI)
      JI=KI-K+J
      A(KI)=A(JI)
   30 A(JI) =HOLD
C
C        INTERCHANGE COLUMNS
C
   35 I=M(K)
      IF(I-K) 45,45,38
   38 JP=N*(I-1)
      DO 40 J=1,N
      JK=NK+J
      JI=JP+J
```

```
      HOLD=-A(JK)
      A(JK)=A(JI)
   40 A(JI) =HOLD
C
C        DIVIDE COLUMN BY MINUS PIVOT (VALUE OF PIVOT ELEMENT IS
C        CONTAINED IN BIGA)
C
   45 IF(BIGA) 48,46,48
   46 D=0.0
      RETURN
   48 DO 55 I=1,N
      IF(I-K) 50,55,50
   50 IK=NK+I
      A(IK)=A(IK)/(-BIGA)
   55 CONTINUE
C
C        REDUCE MATRIX
C
      DO 65 I=1,N
      IK=NK+I
      HOLD=A(IK)
      IJ=I-N
      DO 65 J=1,N
      IJ=IJ+N
      IF(I-K) 60,65,60
   60 IF(J-K) 62,65,62
   62 KJ=IJ-I+K
      A(IJ)=HOLD*A(KJ)+A(IJ)
   65 CONTINUE
C
C        DIVIDE ROW BY PIVOT
C
      KJ=K-N
      DO 75 J=1,N
      KJ=KJ+N
      IF(J-K) 70,75,70
   70 A(KJ)=A(KJ)/BIGA
   75 CONTINUE
C
C        PRODUCT OF PIVOTS
C
      D=D*BIGA
C
C        REPLACE PIVOT BY RECIPROCAL
C
      A(KK)=1.0/BIGA
   80 CONTINUE
C
C        FINAL ROW AND COLUMN INTERCHANGE
C
      K=N
  100 K=(K-1)
      IF(K) 150,150,105
  105 I=L(K)
      IF(I-K) 120,120,108
  108 JQ=N*(K-1)
      JR=N*(I-1)
      DO 110 J=1,N
      JK=JQ+J
      HOLD=A(JK)
```

```
      JI=JR+J
      A(JK)=-A(JI)
  110 A(JI) =HOLD
  120 J=M(K)
      IF(J-K) 100,100,125
  125 KI=K-N
      DO 130 I=1,N
      KI=KI+N
      HOLD=A(KI)
      JI=KI-K+J
      A(KI)=-A(JI)
  130 A(JI) =HOLD
      GO TO 100
  150 RETURN
      END
      SUBROUTINE MNIMX(I,J)
      COMMON/TD/IMIN(100),IMAX(100),JMIN(25),JMAX(25),MAXI,MAXJ,NMTL,NBC
      IF(J.LT.JMIN(I)) JMIN(I)=J
      IF(J.GT.JMAX(I)) JMAX(I)=J
      IF(I.LT.IMIN(J)) IMIN(J)=I
      IF(I.GT.IMAX(J)) IMAX(J)=I
      RETURN
      END
      SUBROUTINE MODIFY(NEQ,N,U)
      COMMON/SOLVE/B( 72),A( 72,36),NUMBLK,MBAND
      DO 10 M=2,MBAND
      K=N-M+1
      IF(K.LE.0) GO TO 5
      B(K)=B(K)-A(K,M)*U
      A(K,M)=0.00
    5 K=N+M-1
      IF(NEQ.LT.K) GO TO 10
      B(K)=B(K)-A(N,M)*U
      A(N,M)=0.00
   10 CONTINUE
      A(N,1)=1.00
      B(N)=U
      RETURN
      END
      SUBROUTINE MPLOT
      INTEGER CODE
      COMMON/TD/IMIN(100),IMAX(100),JMIN(25),JMAX(25),MAXI,MAXJ,NMTL,NBC
      COMMON/NPDATA/R(10  ),CODE(10  ),XR(10  ),Z(10  ),XZ(10  ),
     1NPNUM( 4,  8),T(10  ),XT(10  )
      REAL X(100),Y(100),TX(2),TY(2),TITLE(20),ZMAX
      READ (5,1000) TITLE,RMAX,ZMAX
C     CALL CCP2SY (0.7,0.2,0.2,TITLE,0.0,80)
C     CALL CCP1PL (0.7,0.7,-3)
      TX(1)=0.00
      TY(1)=0.00
      TX(2)=RMAX/9.0
      TY(2)=RMAX/9.0
      ZMAX=ZMAX*TY(2)+2.0
      IF (ZMAX.LT.17.0) ZMAX=17.0
      DO 100 J=1,MAXJ
      NSTART=IMIN(J)
      NSTOP=IMAX(J)
      N=0
      DO 101 I=NSTART,NSTOP
      N=N+1
```

```
      NP=NPNUM(I,J)
      Y(N)=R(NP)
  101 X(N)=Z(NP)
C     CALL CCP6LN (X,Y,N,1,TX,TY)
  100 CONTINUE
      DO 102 I=1,MAXI
      NSTART=JMIN(I)
      NSTOP=JMAX(I)
      N=0
      DO 103 J=NSTART,NSTOP
      N=N+1
      NP=NPNUM(I,J)
      Y(N)=R(NP)
  103 X(N)=Z(NP)
C     CALL CCP6LN (X,Y,N,1,TX,TY)
  102 CONTINUE
C     CALL CCP1PL (ZMAX,-0.7,-3)
 1000 FORMAT (20A4/2F10.0)
      RETURN
      END
      SUBROUTINE NAXSTF(II,JJ,KK)
      INTEGER CODE
      COMMON/VISC/EPSDN(12,10,8),SIGVP(6),DEPSR(6,10,8),DELTIM
       COMMON/PLAS/ALFA(6,   4,8),SIGYLD(7,6,8),IFGPL(   4,8)
      COMMON/NXDATA/NTP,NTS,NTOTS,GTS1G(24,24,8)
      COMMON/MATP/RO(6),E(12,16,6),EE(16),AOFTS(6)
      COMMON/BASIC/ACELZ,ANGVEL,ANGACC,TREF,VOL,NUMNP,NUMEL,NUMPC,NUMSC,
     1NUMST
      COMMON/ARG/RRR(5),ZZZ(5),RR(4),ZZ(4),S(15,15),P(15),TT(6),
     1H(6,15),CRZ(6,6),XI(10),ANGLE(4),SIG(18),EPS(18),N
      COMMON/NPDATA/R(10   ),CODE(10   ),XR(10   ),Z(10   ),XZ(10   ),
     1NPNUM( 4,   8),T(10   ),XT(10   )
      COMMON/ELDATA/BETA(10   ),EPR(10   ),PR(4   ),SH(4   ),IX(8    ,5),
     1IP(4   ),JP(4   ),IS(4   ),JS(4   ),ALPHA(10   ),IT(4   ),JT(4   ),
     2ST(4   )
      COMMON/NXQUAD/AR1
      COMMON/NONAXI/S1(30,30),P1(30),THETA,BS1(6,30)
      DIMENSION C(18,18),B(18,18),B1(6,18),B2(6,18),B3(6,18),B4(6,18),
     1          B5(6,18),B6(6,18),B1A(6,18),B1B(6,18),B2A(6,18),B2B(6,18
     2          ),B3A(6,18),B3B(6,18),B4A(6,18),B4B(6,18),B5A(6,18),
     3          B5B(6,18),B6A(6,18),B6B(6,18),TVP(18)
C     ZERO MATRICES
      DO 100  I=1,18
      DO 100  J=1,18
  100 C(I,J)= 0.0
      DO 110 I=1,6
      DO 110 J=1,18
      B1(I,J) =0.0
      B2(I,J) =0.0
      B3(I,J) =0.0
      B4(I,J) =0.0
      B5(I,J) =0.0
  110 B6(I,J) =0.0
      RR(1) = RRR(II)
      RR(2) = RRR(JJ)
      RR(3) = RRR(KK)
      ZZ(1) = ZZZ(II)
      ZZ(2) = ZZZ(JJ)
      ZZ(3) = ZZZ(KK)
      COMM=RR(2)*(ZZ(3)-ZZ(1))+RR(1)*(ZZ(2)-ZZ(3))+RR(3)*(ZZ(1)-ZZ(2))
```

```
C   FILL  C INVERSE
      C(1,1)= ( RR(2)*ZZ(3) -RR(3)* ZZ(2)) / COMM
      C(1,4)= ( RR(3)*ZZ(1) -RR(1)* ZZ(3)) / COMM
      C(1,7)= ( RR(1)*ZZ(2) -RR(2)* ZZ(1)) / COMM
      C(2,1)= ( ZZ(2) - ZZ(3)) / COMM
      C(2,4)= ( ZZ(3) - ZZ(1)) / COMM
      C(2,7)= ( ZZ(1) - ZZ(2)) / COMM
      C(3,1)= ( RR(3) - RR(2)) / COMM
      C(3,4)= ( RR(1) - RR(3)) / COMM
      C(3,7)= ( RR(2) - RR(1)) / COMM
      C(4,2)= C(1,1)
      C(4,5)= C(1,4)
      C(4,8)= C(1,7)
      C(5,2)= C(2,1)
      C(5,5)= C(2,4)
      C(5,8)= C(2,7)
      C(6,2)= C(3,1)
      C(6,5)= C(3,4)
      C(6,8)= C(3,7)
      C(7,3)= C(1,1)
      C(7,6)= C(1,4)
      C(7,9)= C(1,7)
      C(8,3)= C(2,1)
      C(8,6)= C(2,4)
      C(8,9)= C(2,7)
      C(9,3)= C(3,1)
      C(9,6)= C(3,4)
        C(9,9) = C(3,7)
      DO 120 I=10,18
      DO 120 J= 1,9
      I1 = I-9
      J1=J+9
      C(I,J) =(-1./THETA) * C(I1,J)
      C(I,J1)=( 1./THETA) * C(I1,J)
  120 CONTINUE
C  FILL  B MATRICES
C  B1  CONSTANT TERMS
C  B2  THETA TERMS
C  B3  1/R  TERMS
C  B4  THETA/ R  TERMS
C  B5  Z/R TERMS
C  B6  THETA *Z/R TERMS
      DO  130 J=1,18
      B1(1,J) = C(2,J)
      B1(2,J) = C(6,J)
      B1(3,J) = C(2,J)+C(17,J)
      B1(4,J) = C(3,J)+C(5,J)
      B1(5,J) = C(9,J) +C(14,J)
      B1(6,J) = C(11,J)
      B2(1,J) = C(11,J)
      B2(2,J) = C(15,J)
      B2(3,J) = C(11,J)
      B2(4,J) = C(12,J)+C(14,J)
      B2(5,J) = C(18,J)
      B3(3,J) = C(1,J)+ C(16,J)
      B3(5,J) = C(13,J)
      B3(6,J) = C(10,J) - C(7,J)
      B4(3,J) = C(10,J)
      B4(6,J) = -C(16,J)
      B5(3,J) =  C(3,J) +C(18,J)
```

```
      B5(5,J) =  C(15,J)
      B5(6,J) =  C(12,J)-C(9,J)
      B6(3,J) =  C(12,J)
      B6(6,J) = -C(18,J)
  130 CONTINUE
C NOW CALCULATE  BT * D * B
      CALL INTER
      THETA2 = (THETA **2)/2.0
      THETA3 = (THETA **3)/3.0
      DO 140 I=1,6
      DO 140 J=1,18
      B1A(I,J)=(B1(I,J)*XI(1) +B3(I,J)* XI(2) + B5(I,J)* XI(4))* THETA +
     1         (B2(I,J)*XI(1) +B4(I,J)* XI(2) + B6(I,J)* XI(4))* THETA2
      B2A(I,J)=(B1(I,J)*XI(1) +B3(I,J)* XI(2) + B5(I,J)* XI(4))* THETA2
     1   +     (B2(I,J)*XI(1) +B4(I,J)* XI(2) + B6(I,J)* XI(4))* THETA3
      B3A(I,J)=(B1(I,J)*XI(2) +B3(I,J)* XI(3) + B5(I,J)* XI(5))* THETA
     1        +(B2(I,J)*XI(2) +B4(I,J)* XI(3) + B6(I,J)* XI(5))* THETA2
      B4A(I,J)=(B1(I,J)*XI(2) +B3(I,J)* XI(3) + B5(I,J)* XI(5))* THETA2
     1        +(B2(I,J)*XI(2) +B4(I,J)* XI(3) + B6(I,J)* XI(5))* THETA3
      B5A(I,J)=(B1(I,J)*XI(4) +B3(I,J)* XI(5) + B5(I,J)* XI(6))* THETA
     1       + (B2(I,J)*XI(4) +B4(I,J)* XI(5) + B6(I,J)* XI(6))* THETA2
      B6A(I,J)=(B1(I,J)*XI(4) +B3(I,J)* XI(5) + B5(I,J)* XI(6))* THETA2
     1       + (B2(I,J)*XI(4) +B4(I,J)* XI(5) + B6(I,J)* XI(6))* THETA3
  140 CONTINUE
      DO 150 I=1,6
      DO 150 K=1,18
      B1B(I,K)= 0.0
      B2B(I,K)= 0.0
      B3B(I,K)= 0.0
      B4B(I,K)= 0.0
      B5B(I,K)= 0.0
      B6B(I,K)= 0.0
      DO 150 J=1,6
      B1B(I,K) = B1B(I,K) + CRZ(I,J) * B1A(J,K)
      B2B(I,K) = B2B(I,K) + CRZ(I,J) * B2A(J,K)
      B3B(I,K) = B3B(I,K) + CRZ(I,J) * B3A(J,K)
      B4B(I,K) = B4B(I,K) + CRZ(I,J) * B4A(J,K)
      B5B(I,K) = B5B(I,K) + CRZ(I,J) * B5A(J,K)
      B6B(I,K) = B6B(I,K) + CRZ(I,J) * B6A(J,K)
  150 CONTINUE
      DO 160  I=1,18
      DO 160  K=1,18
       B(I,K)=0.0
      DO 160  J=1,6
      B(I,K) = B(I,K) + B1(J,I)* B1B(J,K)+B2(J,I)*B2B(J,K)+B3(J,I)*
     1     B3B(J,K)+B4(J,I)*B4B(J,K)+B5(J,I)*B5B(J,K)+B6(J,I)*B6B(J,K)
  160 CONTINUE
  250  CONTINUE
C  B(I,K) NOW CONTAINS THE STIFFNESS MATRIX FOR ONE TRIANGULAR ELEMENT
       AR1 = AR1 + XI(1) *THETA
      DO 235 K=1,6
       DO 235 I=1,3
      BS1(K,3*II-3+I) = BS1(K,3*II-3+I) +B1A(K,I   )
      BS1(K,3*JJ-3+I) = BS1(K,3*JJ-3+I) +B1A(K,I+3 )
      BS1(K,3*KK-3+I) = BS1(K,3*KK-3+I) +B1A(K,I+6 )
      BS1(K,3*II+I+12)= BS1(K,3*II+12+I)+B1A(K,I+9 )
      BS1(K,3*JJ+I+12)= BS1(K,3*JJ+12+I)+B1A(K,I+12)
      BS1(K,3*KK+I+12)= BS1(K,3*KK+12+I)+B1A(K,I+15)
  235  CONTINUE
      IIM = 3* II -3
```

```
      JJM = 3* JJ -3
      KKM = 3* KK -3
      DO 170 K=1,4
      DO 170 I=1,3
      DO 170 J=1,3
      IF(K.EQ.1 .OR. K.EQ.2) I1=I
      IF(K.EQ.3 .OR. K.EQ.4) I1=I +9
      IF(K.EQ.1 .OR. K.EQ.3) J1=J
      IF(K.EQ.2 .OR. K.EQ.4) J1=J    +9
      IF(K.EQ.1 .OR. K.EQ.2) K1=0
      IF(K.EQ.3 .OR. K.EQ.4) K1=15
      IF(K.EQ.1 .OR. K.EQ.3) K2=0
      IF(K.EQ.2 .OR. K.EQ.4) K2=15
  182 KK2=KKM
      II2=IIM
      JJ2=JJM
  180 KK1=KKM
      JJ1=JJM
      II1=IIM
       S1(II1+I+K1,II2+J+K2) = S1(II1+I+K1,II2+J+K2) +B(I1,J1)
       S1(II1+I+K1,JJ2+J+K2) = S1(II1+I+K1,JJ2+J+K2) +B(I1,J1+3)
       S1(II1+I+K1,KK2+J+K2) = S1(II1+I+K1,KK2+J+K2) +B(I1,J1+6)
       S1(JJ1+I+K1,II2+J+K2) = S1(JJ1+I+K1,II2+J+K2) +B(I1+3,J1)
       S1(JJ1+I+K1,JJ2+J+K2) = S1(JJ1+I+K1,JJ2+J+K2) +B(I1+3,J1+3)
       S1(JJ1+I+K1,KK2+J+K2) = S1(JJ1+I+K1,KK2+J+K2) +B(I1+3,J1+6)
       S1(KK1+I+K1,II2+J+K2) = S1(KK1+I+K1,II2+J+K2) + B(I1+6,J1)
       S1(KK1+I+K1,JJ2+J+K2) = S1(KK1+I+K1,JJ2+J+K2) + B(I1+6,J1+3)
       S1(KK1+I+K1,KK2+J+K2) = S1(KK1+I+K1,KK2+J+K2) + B(I1+6,J1+6)
  170  CONTINUE
       IF(IFGPL(N,NTP).EQ.0) GO TO 190
       DO 174  I=1,18
       TVP(I)=0.0
       DO 174 J=1,6
  174  TVP(I)=TVP(I)+B1A(J,I)*EPSDN(J,N,NTP)
       K=3*II-2
       L=3*JJ-2
       M=3*KK-2
       DO 179 I=1,3
       J=I-1
       P1(K+J)=P1(K+J)-TVP(I)
       P1(K+J+15)=P1(K+J+15)-TVP(I+9)
       P1(L+J)=P1(L+J)-TVP(I+3)
       P1(L+J+15)=P1(L+J+15)-TVP(I+12)
       P1(M+J)=P1(M+J)-TVP(I+6)
 179   P1(M+J+15)=P1(M+J+15)-TVP(I+15)
  190  CONTINUE
       RETURN
       END
      FUNCTION NODE(I,J)
      COMMON/TD/IMIN(100),IMAX(100),JMIN(25),JMAX(25),MAXI,MAXJ,NMTL,NBC
      NODE=0
      DO 100 JJ=1,J
      NSTART=IMIN(JJ)
      NSTOP=IMAX(JJ)
      DO 100 II=NSTART,NSTOP
      NODE=NODE+1
      IF(JJ.EQ.J.AND.II.EQ.I) RETURN
  100 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE POINTS
      INTEGER CODE
      COMMON/BASIC/ACELZ,ANGVEL,ANGACC,TREF,VOL,NUMNP,NUMEL,NUMPC,NUMSC,
     1NUMST
      COMMON/MATP/RO(6),E(12,16,6),EE(16),AOFTS(6)
      COMMON/NPDATA/R(10   ),CODE(10   ),XR(10  ),Z(10   ),XZ(10   ),
     1NPNUM( 4,   8),T(10   ),XT(10   )
      COMMON/ELDATA/BETA(10   ),EPR(10   ),PR(4  ),SH(4   ),IX(8    ,5),
     1IP(4   ),JP(4   ),IS(4   ),JS(4   ),ALPHA(10   ),IT(4   ),JT(4   ),
     2ST(4   )
      COMMON/SOLVE/X(888),Y(888),TEM(888),NUMTC,MBAND
      COMMON/TD/IMIN(100),IMAX(100),JMIN(25),JMAX(25),MAXI,MAXJ,NMTL,NBC
      COMMON/PLANE/NPP
      DIMENSION AR( 4,   8),AZ( 4,   8),MATRIL(100,5),BLKANG(100),BLKALF(1
     100)
      DIMENSION IBNG(100),NBNG(100)
      EQUIVALENCE (R(1),AR),(Z(1),AZ)
C     ESTABLISH NODAL POINT INFORMATION
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      NEL=0
      NODSUM=0
      DO 100 J=1,MAXJ
      NSTART=IMIN(J)
      NSTOP=IMAX(J)
      DO 100 I=NSTART,NSTOP
  100 NODSUM=NODSUM+1
      NELSUM=0
      JJMAX=MAXJ-1
      DO 110 JJ=1,JJMAX
      NSTOP=MIN0(IMAX(JJ),IMAX(JJ+1))-1
      NSTART=MAX0(IMIN(JJ),IMIN(JJ+1))
      DO 110 II=NSTART,NSTOP
  110 NELSUM=NELSUM+1
      NUMNP=NODSUM
      NUMEL=NELSUM
       WRITE(15)NUMEL,NUMNP
      DO 120 J=1,MAXJ
      NSTART=IMIN(J)
      NSTOP=IMAX(J)
      DO 120 I=NSTART,NSTOP
      NPNUM(I,J)=NODE(I,J)
      NP=NPNUM(I,J)
      R(NP)=AR(I,J)
  120 Z(NP)=AZ(I,J)
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     READ AND ASSIGN BOUNDARY CONDITIONS
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     INITIALIZE
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      DO 130 I=1,NUMNP
      CODE(I)=0
      IF(R(I).EQ.0..AND.NPP.EQ.0) CODE(I)=1.
      XR(I)=0.
      XZ(I)=0.
      XT(I)=0.0
  130 T(I)=0.
      IF(NBC.EQ.0) GO TO 210
      DO 200 IBCON=1,NBC
      READ(5,1002) I1,I2,J1,J2,ICN,RCON,ZCON,TCON
      DO 200 I=I1,I2
```

```
      DO 200 J=J1,J2
      NP=NPNUM(I,J)
      CODE(NP)=ICN
      XR(NP)=RCON
      XT(NP)=TCON
      XZ(NP)=ZCON
  200  CONTINUE
  210 MPRINT=0
       WRITE(15)(CODE(I),I=1,NUMNP)
       WRITE(15)(   XR(I),I=1,NUMNP)
       WRITE(15)(   XT(I),I=1,NUMNP)
       WRITE(15)(   XZ(I),I=1,NUMNP)
      DO 230 J=1,MAXJ
      NSTART=IMIN(J)
      NSTOP=IMAX(J)
      DO 230 I=NSTART,NSTOP
      NP=NPNUM(I,J)
      IF(MPRINT.NE.0) GO TO 220
      WRITE(6,2000)
      MPRINT=59
  220 MPRINT=MPRINT-1
  230 WRITE(6,2001) I,J,NP,CODE(NP),R(NP),Z(NP),XR(NP),XZ(NP),XT(NP)
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     ASSIGN MATERIALS IN BLOCKS
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      DO 300 M1=1,NUMEL
  300 IX(M1,5)=0
      DO 310 IMTL=1,NMTL
      READ (5,1000) MTL,(MATRIL(IMTL,IM),IM=2,5),BLKANG(IMTL),BLKALF(IMT
     1L),IBNG(IMTL),NBNG(IMTL)
  310 MATRIL(IMTL,1)=MTL
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     ESTABLISH ELEMENT INFORMATION
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      JJMAX=MAXJ-1
      N=0
      MTL=1
      KTL=1
      DO 440 JJ=1,JJMAX
      NSTOP=MIN0(IMAX(JJ),IMAX(JJ+1))-1
      NSTART=MAX0(IMIN(JJ),IMIN(JJ+1))
      DO 440 II=NSTART,NSTOP
      NEL=NEL+1
      DO 400 IMTL=1,NMTL
      IF(II.LT.MATRIL(IMTL,2)) GO TO 400
      IF(II.GE.MATRIL(IMTL,3)) GO TO 400
      IF(JJ.LT.MATRIL(IMTL,4)) GO TO 400
      IF(JJ.GE.MATRIL(IMTL,5)) GO TO 400
      KAT=IMTL
      MAT=MATRIL(IMTL,1)
  400 CONTINUE
      IF(KAT.EQ.KTL) GO TO 410
      KTL=KAT
      MTL=MAT
      GO TO 420
  410 IF(II.EQ.NSTART) GO TO 420
      IF(JJ.NE.JJMAX.OR.II.NE.NSTOP) GO TO 440
      M=NEL+1
      IANG=ICNG
      NANG=NCNG
```

```
      GO TO 421
  420 I=NPNUM(II,JJ)
      J=I+1
      K=NPNUM(II+1,JJ+1)
      L=K-1
      M=NEL
      IX(M,1)=I
      IX(M,2)=J
      IX(M,3)=K
      IX(M,4)=L
      IX(M,5)=MTL
      BETA(M)=BLKANG(KTL)
      ALPHA(M)=BLKALF(KTL)
      IANG=ICNG
      NANG=NCNG
      ICNG=IBNG(KTL)
      NCNG=NBNG(KTL)
421   NC=2
  430 N=N+1
      IF(M.LE.N) GO TO 440
      IX(N,1)=IX(N-1,1)+1
      IX(N,2)=IX(N-1,2)+1
      IX(N,3)=IX(N-1,3)+1
      IX(N,4)=IX(N-1,4)+1
      IX(N,5)=IX(N-1,5)
      BETA(N)=BETA(N-1)
      IF(IANG.EQ.1) GO TO 442
      ALPHA(N)=ALPHA(N-1)
      GO TO 443
  442 CONTINUE
      IF(NC.GT.NANG) GO TO 444
      ALPHA(N)=ALPHA(N-1)
      GO TO 443
  444 NC=1
      ALPHA(N)=-ALPHA(N-1)
  443 CONTINUE
      NC=NC+1
      IF(M.GT.N) GO TO 430
  440 CONTINUE
      IF(NUMNP.GT.2000) WRITE(6,2002)
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     SET NODAL POINT TEMPERATURE TO REFERENCE TEMPERATURE
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      IF(NUMTC.NE.0) RETURN
      DO 500 N=1,NUMNP
  500 T(N)=TREF
 1000 FORMAT (5I5,2F10.0,2I5)
 1002 FORMAT(4I5,I10,3F10.0)
 2000 FORMAT (128H1    I     J     NP          TYPE      R-ORDINATE     Z-ORDINA
     1TE   R LOAD OR DISPLACEMENT   Z LOAD OR DISPLACEMENT   T LOAD OR DISP
     2LACEMENT)
 2001 FORMAT (2I5,I6,I12,F13.6,F14.6,E26.7,E24.7,E24.7)
 2002 FORMAT (35H  BAD INPUT - TOO MANY NODAL POINTS)
      RETURN
      END
      SUBROUTINE QUAD
      INTEGER CODE
      REAL NUSN,NUTN,NUTS,NUNS,NUNT,NUST
      DIMENSION DUMMY(6,6),DUMMY1(6,6)
       COMMON/PLAS/ALFA(6,   4,8),SIGYLD(7,6,8),IFGPL(   4,8)
```

```
      COMMON/ARG1/SIG1(18),EPS1(18),DEFSP(12),CEPSP(6,6)
      COMMON/NXDATA/NTP,NTS,NTOTS,GTSIG(24,24,8)
      COMMON/BASIC/ACELZ,ANGVEL,ANGACC,TREF,VOL,NUMNP,NUMEL,NUMPC,NUMSC,
     1NUMST
      COMMON/NXQUAD/AR1
      COMMON/NONAXI/S1(30,30),P1(30),THETA,BS1(6,30)
      COMMON/MATP/RO(6),E(12,16,6),EE(16),ADFTS(6)
      COMMON/NPDATA/R(10   ),CODE(10   ),XR(10   ),Z(10   ),XZ(10   ),
     1NPNUM( 4,  8),T(10   ),XT(10   )
      COMMON/ELDATA/BETA(10   ),EPR(10   ),PR(4   ),SH(4   ),IX(8    ,5),
     1IP(4   ),JP(4   ),IS(4   ),JS(4   ),ALPHA(10   ),IT(4   ),JT(4   ),
     2ST(4   )
      COMMON/ARG/RRR(5),ZZZ(5),RR(4),ZZ(4),S(15,15),P(15),TT(6),
     1H(6,15),CRZ(6,6),XI(10),ANGLE(4),SIG(18),EPS(18),N
      COMMON/INCR/NOLINC,NOL,INERT,NUMMAT,SIGTOT(12,  4,8)
      COMMON/RESULT/BS(6,15),D(6,6),C(6,6),AR,BB(6,9),CNS(6,6)
      COMMON/PLANE/NPP
      COMMON/DUM1/S1TEM(3,30),S1T(24,24),TS(6,24)
      DIMENSION S2T(24,6)
      DIMENSION BS1T(6,3)  ,P1T(3) ,P1TT(24)
      I1=IX(N,1)
      J1=IX(N,2)
      K1=IX(N,3)
      L1=IX(N,4)
      MTYPE=IX(N,5)
      IX(N,5)=-IX(N,5)
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     INTERPOLATE MATERIAL PROPERTIES
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      DO 100 I=1,12
  100 EE(I)=E(1,I+1,MTYPE)
      DO 110 I=1,6
      DO 110 J=1,6
      CNS(I,J)=0.00
      C(I,J)=0.00
  110 D(I,J)=0.00
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     FORM STRESS-STRAIN RELATIONSHIP IN N-S-T SYSTEM
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      NUNS=EE(4)
      NUNT=EE(5)
      NUST=EE(6)
      NUSN=(EE(2)*NUNS)/EE(1)
      NUTN=(EE(3)*NUNT)/EE(1)
      NUTS=(EE(3)*NUST)/EE(2)
      DIV=1.00-NUNS*NUSN-NUST*NUTS-NUNT*NUTN-NUSN*NUNT*NUTS
     1-NUNS*NUTN*NUST
      CNS(1,1)=EE(1)*(1.00-NUST*NUTS)/DIV
      CNS(1,2)=EE(2)*(NUNS+NUNT*NUTS)/DIV
      CNS(1,3)=EE(3)*(NUNT+NUNS*NUST)/DIV
      CNS(2,1)=CNS(1,2)
      CNS(2,2)=EE(2)*(1.00-NUNT*NUTN)/DIV
      CNS(2,3)=EE(3)*(NUST+NUSN*NUNT)/DIV
      CNS(3,1)=CNS(1,3)
      CNS(3,2)=CNS(2,3)
      CNS(3,3)=EE(3)*(1.00-NUNS*NUSN)/DIV
      CNS(4,4)=EE(7)
      CNS(5,5)=EE(8)
      CNS(6,6)=EE(9)
      DO 162 I=1,6
```

```
      DO 162 J=1,6
  162 CEPSP(I,J)=0.0
C     IF (IFGPL(N,NTP).NE.0)CALL ELPLSS(MTYPE)
C     SET UP STRAIN TRANSFORM TO N-S-T SYSTEM
      SINA=SIN(ALPHA(N))
      COSA=COS(ALPHA(N))
      S2=SINA**2
      C2=COSA**2
      SC=SINA*COSA
      D(1,1)=C2
      D(1,3)=S2
      D(1,6)=-SC
      D(2,1)=S2
      D(2,3)=C2
      D(2,6)=SC
      D(3,2)=1.00
      D(4,1)=2.00*SC
      D(4,3)=-2.00*SC
      D(4,6)=C2-S2
      D(5,4)=SINA
      D(5,5)=COSA
      D(6,4)=COSA
      D(6,5)=-SINA
C     SET UP STRAIN TRANSFORMATION TO R-Z-T SYSTEM
      SINB=SIN(BETA(N))
      COSB=COS(BETA(N))
      S2=SINB**2
      C2=COSB**2
      SC=SINB*COSB
      C(1,1)=S2
      C(1,2)=C2
      C(1,4)=SC
      C(2,1)=C2
      C(2,2)=S2
      C(2,4)=-SC
      C(3,3)=1.00
      C(4,1)=-2.00*SC
      C(4,2)=2.00*SC
      C(4,4)=S2-C2
      C(5,5)=SINB
      C(5,6)=-COSB
      C(6,5)=COSB
      C(6,6)=SINB
       IF (IFGPL(N,NTP).NE.0)CALL ELPLSS(MTYPE)
C     CALCULATE CRZ MATRIX
      DO 120 I=1,6
      DO 120 J=1,6
      DUMMY(I,J)=0.00
      DO 120 K=1,6
  120 DUMMY(I,J)=DUMMY(I,J)+D(I,K)*C(K,J)
      DO 130 I=1,6
      DO 130 J=1,6
      DUMMY1(I,J)=0.00
      DO 130 K=1,6
  130 DUMMY1(I,J)=DUMMY1(I,J)+CNS(I,K)*DUMMY(K,J)
      DO 140 I=1,6
      DO 140 J=1,6
      DUMMY(I,J)=0.00
      DO 140 K=1,6
  140 DUMMY(I,J)=DUMMY(I,J)+D(K,I)*DUMMY1(K,J)
```

```
      DO 160 I=1,6
      DO 150 J=1,6
      CRZ(I,J)=0.00
      DO 150 K=1,6
  150 CRZ(I,J)=CRZ(I,J)+C(K,I)*DUMMY(K,J)
      TT(I)=0.00
      DO 160 M=1,6
      P(M)=0.00
      DO 161 II=1,3
      IF(AOFTS(MTYPE).EQ.1.) P(M)=CNS(M,II)*EE(II+9)
  161 P(M)=P(M)+(T(N)-TREF)*CNS(M,II)*EE(II+9)
      DO 160 K=1,6
  160 TT(I)=TT(I)+C(K,I)*D(M,K)*P(M)
C
C     FORM QUADRILATERAL STIFFNESS MATRIX
      RRR(5)=(R(I1)+R(J1)+R(K1)+R(L1))/4.
      ZZZ(5)=(Z(I1)+Z(J1)+Z(K1)+Z(L1))/4.
      DO 200 M=1,4
      MM=IX(N,M)
      IF(NPP.NE.0) GO TO 190
      IF(R(MM).EQ.0..AND.CODE(MM).EQ.0.)CODE(MM)=1.
  190 RRR(M)=R(MM)
  200 ZZZ(M)=Z(MM)
      DO 220 II=1,15
      P1(II)=0.0
      P1(II+15) =0.0
      P(II)=0.00
      DO 220 JJ=1,15
  220 S(II,JJ)=0.00
      VOL=0.
      DO 90 I=1,6
      DO 90 J=1,15
      BS1(I,J)=0.0
       BS1(I,J+15) = 0.0
90    BS(I,J)=0.00
      AR=0.00
  240 CALL TRISTF(4,1,5)
      CALL TRISTF(1,2,5)
      CALL TRISTF(2,3,5)
      CALL TRISTF(3,4,5)
      DO 91 I=1,6
      DO 91 J=1,15
91    BS(I,J)=BS(I,J)/AR
       DO 300 I=1,30
       DO 300 J=1,30
  300   S1(I,J)=0.0
       AR1 =0.0
       CALL NAXSTF(4,1,5)
       CALL NAXSTF(1,2,5)
       CALL NAXSTF(2,3,5)
       CALL NAXSTF(3,4,5)
       DO 310 I=1,6
       DO 310 J=1,30
  310  BS1(I,J)= BS1(I,J)/AR1
      DO 320 I=1,6
       DO 320 J=1,3
  320 BS1T(I,J) = BS1(I,J+12)
      DO 325 I=1,6
      DO 325 J=1,12
  325 BS1(I,J+12) = BS1(I,J+15)
```

```
      DO 330 I=1,6
      DO 330 J=1,3
  330 BS1(I,J+24) = BS1T(I,J)
      DO 340 I=1,3
  340 P1T (I) = P1(I+12)
      DO 341 I=1,12
  341 P1(I+12) = P1(I+15)
      DO 342 I=1,3
  342 P1(I+24) = P1T(I)
       DO 149  I=1,3
       DO 149  J=1,30
  149   S1TEM(I,J) = S1(I+12,J)
      DO 151 I=1,12
      DO 151 J=1,30
  151 S1(I+12,J) = S1(I+15,J)
      DO 152 I=1,3
      DO 152 J=1,30
  152 S1(I+24,J) = S1TEM(I,J)
      DO 153 I=1,3
      DO 153 J=1,30
  153 S1TEM(I,J) = S1(J,I+12)
      DO 154 J=1,12
      DO 154 I=1,30
  154 S1(I,J+12) = S1(I,J+15)
      DO 155 I=1,3
      DO 155 J=1,30
  155 S1(  J,I+24) = S1TEM(I,J)
       DO 251 I=1,6
       DO 251 J=1,24
  251 TS(I,J) = 0.0
       DO 252 I=1,3
       DO 252 J=1,4
       TS(I,I+(J-1)*3) = 0.250
  252 TS(I+3,I+12+(J-1)*3) = 0.250
       DO 253 I=1,24
       DO 253 J=1,24
       S1T(I,J) = 0.00
       DO 253 K=1,6
  253  S1T(I,J) = S1T(I,J) + S1(I,24+K)*TS(K,J)
       DO 254 I=1,24
       DO 254 J=1,24
  254  S1(I,J) = S1(I,J) + S1T(I,J) + S1T(J,I)
       DO 255 I=1,24
       DO 255 J=1,6
       S2T(I,J) = 0.0
       DO 255  K=1,6
  255  S2T(I,J) = S2T(I,J) +TS(K,I)*S1(K+24,J+24)
       DO 256  I=1,24
       DO 256  J=1,24
        S1T(I,J)  = 0.0
        DO 256  K=1,6
  256. S1T(I,J) = S1T(I,J) + S2T(I,K)*TS(K,J)
       DO 257  I=1,24
       DO 257  J =1,24
  257   S1(I,J)  =S1(I,J)+S1T(I,J)
       DO 258 I=1,24
       P1TT(I)=0.0
       DO 258 K=1,6
  258  P1TT(I)=P1TT(I)+TS(K,I)*P1(K+24)
       DO 259 I=1,24
```

```
  259 P1(I)=P1(I)+P1TT(I)
      RETURN
      END
      SUBROUTINE SOLV
      COMMON/ELDATA/BETA(10   ),EPR(10   ),PR(4   ),SH(4   ),IX(8    ,5),
     1IP(4   ),JP(4   ),IS(4   ),JS(4   ),ALPHA(10   ),IT(4   ),JT(4   ),
     2ST(4   )
      COMMON/BASIC/ACELZ,ANGVEL,ANGACC,TREF,VOL,NUMNP,NUMEL,NUMPC,NUMSC,
     1NUMST
      COMMON/NONAXI/S1(30,30),P1(30),THETA,BS1(6,30)
      COMMON/NXDATA/NTP,NTS,NTOTS,GTS1G(24,24,8)
      COMMON/SOLVE/B( 72),A( 72,36),NUMBLK,MBAND
      MM=MBAND
      NN=36
      NL=NN+1
      NH=NN+NN
      REWIND 1
      REWIND 2
      NB=0
      GO TO 150
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     REDUCE EQUATIONS BY BLOCKS
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C
C     1. SHIFT BLOCK OF EQUATIONS
C
  100 NB=NB+1
      DO 125 N=1,NN
      NM=NN+N
      B(N)=B(NM)
      B(NM)=0.00
      DO 125 M=1,MM
      A(N,M)=A(NM,M)
  125 A(NM,M)=0.00
C
C     2. READ NEXT BLOCK OF EQUATIONS INTO CORE
C
      IF(NUMBLK.EQ.NB) GO TO 200
  150 READ(2) (B(N),(A(N,M),M=1,MM),N=NL,NH)
      IF(NB.EQ.0) GO TO 100
C
C     3. REDUCE BLOCK OF EQUATIONS
C
  200 DO 300 N=1,NN
      IF(A(N,1).EQ.0.00) GO TO 300
      B(N)=B(N)/A(N,1)
      DO 275 L=2,MM
      IF(A(N,L).EQ.0.00) GO TO 275
      C=A(N,L)/A(N,1)
      I=N+L-1
      J=0
      DO 250 K=L,MM
      J=J+1
  250 A(I,J)=A(I,J)-C*A(N,K)
      B(I)=B(I)-A(N,L)*B(N)
      A(N,L)=C
  275 CONTINUE
  300 CONTINUE
C
C     4. WRITE BLOCK OF REDUCED EQUATIONS ON FORTRAN UNIT 1
```

```
C
      IF(NUMBLK.EQ.NB) GO TO 400
      WRITE (1) (B(N),(A(N,M),M=2,MM),N=1,NN)
      GO TO 100
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     BACK-SUBSTITUTION
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
  400 DO 450 M=1,NN
      N=NN+1-M
      DO 425 K=2,MM
      L=N+K-1
  425 B(N)=B(N)-A(N,K)*B(L)
      NM=N+NN
      B(NM)=B(N)
  450 A(NM,NB)=B(N)
      NB=NB-1
      IF(NB.EQ.0) GO TO 500
      BACKSPACE 1
      READ (1) (B(N),(A(N,M),M=2,MM),N=1,NN)
      BACKSPACE 1
      GO TO 400
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     ORDER FORMER UNKNOWNS IN B ARRAY
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
  500 K=0
      DO 600 NB=1,NUMBLK
      DO 600 N=1,NN
      NM=N+NN
      K=K+1
  600 B(K)=A(NM,NB)
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     WRITE SOLUTION
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
       NN12 = 3*NUMNP
 1500 FORMAT(" ",5I10)
       WRITE(26) (B(I),I=1,NN12)
       WRITE(26)((IX(I,J),J=1,5),I=1,NUMEL)
      MPRINT=0
      DO 710 N=1,NUMNP
      IF(MPRINT.NE.0) GO TO 700
      WRITE (6,2000)
      MPRINT=59
  700 MPRINT=MPRINT-1
  710 WRITE (6,2001) N,B(3*N-2),B(3*N-1),B(3*N)
 2000 FORMAT (13H1 NODAL POINT,18X,2HUR,18X,2HUZ,18X,2HUT)
 2001 FORMAT (I13,3E20.7)
      RETURN
      END
      SUBROUTINE STIFF
      INTEGER CODE
       COMMON/RESULT/BS(6,15),D(6,6),C(6,6),AR,BB(6,9),CNS(6,6)
       COMMON/ARG1/SIG1(18),EPS1(18),DEPSP(12),CEPSP(6,6)
      COMMON/BASIC/ACELZ,ANGVEL,ANGACC,TREF,VOL,NUMNP,NUMEL,NUMPC,NUMSC,
     1NUMST
      COMMON/ELDATA/BETA(10   ),EPR(10   ),PR(4   ),SH(4   ),IX(8    ,5),
     1IP(4   ),JP(4   ),IS(4   ),JS(4   ),ALPHA(10   ),IT(4   ),JT(4   ),
     2ST(4   )
      COMMON/NPDATA/R(10   ),CODE(10   ),XR(10   ),Z(10   ),XZ(10   ),
     1NPNUM( 4,    8),T(10   ),XT(10   )
      COMMON/SOLVE/B( 72),A( 72,36),NUMBLK,MBAND
```

```
      COMMON/NXDATA/NTP,NTS,NTOTS,GTS1G(24,24,8)
       COMMON/ANS4/FT(24,4),GTS1U(24),GTS1UT(24,4)
      COMMON/ARG/RRR(5),ZZZ(5),RR(4),ZZ(4),S(15,15),P(15),TT(6),
     1H(6,15),CRZ(6,6),XI(10),ANGLE(4),SIG(18),EPS(18),N
      COMMON/NONAXI/S1(30,30),P1(30),THETA,BS1(6,30)
      COMMON/PLANE/NPP
      COMMON/ANS2/GTP1(24),G(24,24),GTS1(24,24),GTS1GE(24,24)
      COMMON/DUM1/S1TEM(3,30),S1T(24,24),TS(6,24)
      COMMON/RATE/DKPR,SIGPR,BVR,EVR,PSRATE( 10,8),NRATE
      DIMENSION LM(4),S2(12,3),S3(3,12),S4(3,3),S5(12,3),S6(12,12)
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     INITIALIZATION
      NRATE=1
      REWIND 2
        REWIND 3
      NB=12
      ND=3*NB
      ND2=2*ND
      STOP=0.
      NUMBLK=0
      DO 100 N=1,ND2
      B(N)=0.00
      DO 100 M=1,ND
  100 A(N,M)=0.00
       DO 50 I=1,24
       FT(I,NTP) = 0.0
       GTS1UT(I,NTP)=0.0
       DO 50 J=1,24
   50  GTS1G(I,J,NTP) = 0.0
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     FORM STIFFNESS MATRIX IN BLOCKS
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
  200 NUMBLK=NUMBLK+1
      NH=NB*(NUMBLK+1)
      NM=NH-NB
      NL=NM-NB+1
      KSHIFT=3*NL-3
      DO 340 N=1,NUMEL
      IF(IX(N,5).LE.0) GO TO 340
      DO 210 I=1,4
      IF(IX(N,I).LT.NL) GO TO 210
      IF(IX(N,I).LE.NM) GO TO 220
  210 CONTINUE
      GO TO 340
  220 CALL QUAD
      IF(VOL.GT.0.) GO TO 230
      WRITE(6,2000) N
      STOP=1.
  230 IF(IX(N,3).EQ.IX(N,4)) GO TO 300
      DO 231 II=1,3
      DO 231 JJ=1,3
  231 S4(II,JJ)=S(II+12,JJ+12)
      CALL SYMINV(S4,3)
      DO 232 II=1,12
      DO 232 JJ=1,3
  232 S2(II,JJ)=S(II,JJ+12)
      DO 233 II=1,3
      DO 233 JJ=1,12
  233 S3(II,JJ)=S(II+12,JJ)
      DO 240 I=1,12
```

```
      DO 240 J=1,3
      S5(I,J)=0.00
      DO 240 K=1,3
  240 S5(I,J) = S5(I,J) + S2(I,K) * S4(K,J)
      DO 241 I=1,12
      DO 241 J=1,12
      S6(I,J)=0.00
      DO 241 K=1,3
  241 S6(I,J) = S6(I,J) + S5(I,K) * S3(K,J)
      DO 234 II=1,12
      DO 234 JJ=1,3
  234 P(II)=P(II)-S5(II,JJ)*P(JJ+12)
      DO 235 II=1,12
      DO 235 JJ=1,12
  235 S(II,JJ)=S(II,JJ)-S6(II,JJ)
      DO 259 I=1,24
      DO 259 J=1,24
  259 G(I,J) = 0.0
      DO 260 K=1,4
      DO 260 I=1,3
       G(K*3-3+I,I*4-3) =1.0
       G(K*3-3+I,I*4-2) = RRR(K)
       G(K*3-3+I,I*4-1) = ZZZ(K)
  260  G(K*3-3+I,I*4   ) = ZZZ(K)    *RRR(K)
        DO 262 I=1,12
        DO 262 J=1,12
  262 G(I+12,J+12) = G(I,J)
      NTP20 = 21
       WRITE(NTP20) ((  CRZ(I,J),J=1,6),I=1,6)
       WRITE(NTP20)((BS1(I,J),J=1,30),I=1,6)
       WRITE(NTP20)((G(I,J),J=1,24),I=1,24)
       WRITE(NTP20)((CEPSP(I,J),J=1,6),I=1,6)
       WRITE(NTP20)((CNS(I,J),J=1,6),I=1,6)
       WRITE(NTP20)((D(I,J),J=1,6),I=1,6)
       WRITE(NTP20)((C(I,J),J=1,6),I=1,6)
      DO 280 I=1,24
       GTP1(I)=0.0
      DO 280 K=1,24
      GTS1(I,K) = 0.0
      GTP1(I)= GTP1(I)+ G(K,I)*P1(K)
      DO 280 J=1,24
  280 GTS1(I,K) = GTS1(I,K) + G(J,I) * S1(J,K)
       WRITE(3) ((GTS1(I,J),J=1,24),I=1,24)
      DO 281 I=1,24
       FT(I,NTP) =FT(I,NTP) + GTP1(I)
      DO 281 J=1,24
      GTS1GE(I,J) = 0.0
      DO 281 K=1,24
  281 GTS1GE(I,J) = GTS1GE(I,J)+ GTS1(I,K) *G(K,J)
       DO 282 I=1,24
       DO 282 J=1,24
  282 GTS1G(I,J,NTP) = GTS1G(I,J,NTP) + GTS1GE(I,J)
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     ADD ELEMENT STIFFNESS MATRIX TO BODY STIFFNESS MATRIX
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
  300 DO 310 I=1,4
310   LM(I)=3*IX(N,I)-3
      DO 330 I=1,4
      DO 330 K=1,3
      II=LM(I)+K-KSHIFT
```

```
      KK=3*I-3+K
      B(II)=B(II)+P(KK)
      DO 330 J=1,4
      DO 330 L=1,3
      JJ=LM(J)+L-II+1-KSHIFT
      LL=3*J-3+L
      IF(JJ.LE.0) GO TO 330
      IF(ND.GE.JJ) GO TO 320
      WRITE(6,2001) N
      STOP=1.
      GO TO 340
  320 A(II,JJ)=A(II,JJ)+S(KK,LL)
  330 CONTINUE
  340 CONTINUE
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     ADD CONCENTRATED FORCES
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      DO 400 N=NL,NM
      IF(N.GT.NUMNP) GO TO 500
      K=3*N-KSHIFT
      B(K)=B(K)+XT(N)
      B(K-1)=B(K-1)+XZ(N)
  400 B(K-2)=B(K-2)+XR(N)
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     ADD PRESSURE BOUNDARY CONDITIONS
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
  500 IF(NUMPC.EQ.0) GO TO 600
      DO 540 L=1,NUMPC
      I=IP(L)
      J=JP(L)
      PP=PR(L)/6.
      DR=(R(J)-R(I))*PP
      DZ=(Z(I)-Z(J))*PP
      RX=2.*R(I)+R(J)
      ZX=R(I)+2.*R(J)
      II=3*I-KSHIFT-1
      JJ=3*J-KSHIFT-1
      IF(II.LE.0.OR.II.GT.ND) GO TO 520
      SINA=0.
      COSA=1.
  510 B(II-1)=B(II-1)+RX*(COSA*DZ+SINA*DR)
        GR=RX*(COSA*DZ+SINA*DR)*THETA/2.0
        FT(1,NTP) = FT(1,NTP)+GR
        FT(2,NTP) = FT(2,NTP) +R(I)*GR
        FT(3,NTP) = FT(3,NTP) +Z(I)*GR
        FT(4,NTP) = FT(4,NTP) + R(I)*Z(I)*GR
        FT(14,NTP)= FT(14,NTP) +R(I)*GR
        FT(13,NTP)  = FT(13,NTP) +GR
        FT(15,NTP) = FT(15,NTP)+Z(I)*GR
        FT(16,NTP) = FT(16,NTP) +Z(I)*R(I)*GR
      B(II)=B(II)-RX*(SINA*DZ-COSA*DR)
      GZ=-RX*(SINA*DZ-COSA*DR) *THETA/2.0
        FT(5,NTP)=FT(5,NTP)+GZ
        FT(6,NTP)=FT(6,NTP)+R(I)*GZ
        FT(7,NTP)=FT(7,NTP)+ Z(I)*GZ
        FT(8,NTP)=FT(8,NTP)+Z(I)*R(I)*GZ
        FT(17,NTP)=FT(17,NTP)+GZ
        FT(18,NTP)=FT(18,NTP)+R(I)*GZ
        FT(19,NTP)=FT(19,NTP)+Z(I)*GZ
        FT(20,NTP)=FT(20,NTP)+Z(I)*R(I)*GZ
```

```
  520 IF(JJ.LE.0.OR.JJ.GT.ND) GO TO 540
      SINA=0.
      COSA=1.
  530 B(JJ-1)=B(JJ-1)+ZX*(COSA*DZ+SINA*DR)
       GR= ZX *(COSA*DZ+SINA*DR)  *THETA/2.0
       FT(1,NTP)=FT(1,NTP)+GR
       FT(2,NTP)=FT(2,NTP)+R(J)*GR
       FT(3,NTP)=FT(3,NTP)+Z(J)*GR
       FT(4,NTP)=FT(4,NTP)+Z(J)*R(J)*GR
       FT(13,NTP)=FT(13,NTP)+GR
       FT(14,NTP)=FT(14,NTP)+R(J)*GR
       FT(15,NTP)=FT(15,NTP)+Z(J)*GR
       FT(16,NTP)=FT(16,NTP)+Z(J)*R(J)*GR
      B(JJ)=B(JJ)-ZX*(SINA*DZ-COSA*DR)
        GZ= -ZX*(SINA*DZ-COSA*DR) *THETA/2.0
       FT(5,NTP)=FT(5,NTP)+GZ
       FT(6,NTP)=FT(6,NTP)+R(J)*GZ
       FT(7,NTP)=FT(7,NTP) +Z(J)*GZ
       FT(8,NTP)=FT(8,NTP)+Z(J)*R(J)*GZ
       FT(17,NTP)=FT(17,NTP)+GZ
       FT(18,NTP)=FT(18,NTP)+R(J)*GZ
       FT(19,NTP)=FT(19,NTP)+Z(J)*GZ
       FT(20,NTP)=FT(20,NTP)+Z(J)*R(J)*GZ
  540 CONTINUE
 1100  FORMAT(" ",12E10.3)
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     ADD SHEAR BOUNDARY CONDITIONS
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
  600 IF(NUMSC.EQ.0) GO TO 701
      DO 640 L=1,NUMSC
      I=IS(L)
      J=JS(L)
      SS=SH(L)/6.
      DZ=(Z(I)-Z(J))*SS
      DR=(R(J)-R(I))*SS
      RX=2.*R(I)+R(J)
      ZX=R(I)+2.*R(J)
      II=3*I-KSHIFT-1
      JJ=3*J-KSHIFT-1
      IF(II.LE.0.OR.II.GT.ND) GO TO 620
      SINA=0.
      COSA=1.
  610 B(II-1)=B(II-1)+RX*(SINA*DZ+COSA*DR)
       GR= RX*(SINA*DZ+COSA*DR) *THETA/2.0
       FT(1,NTP)=FT(1,NTP)+GR
       FT(2,NTP)=FT(2,NTP)+R(I)*GR
       FT(3,NTP) =FT(3,NTP)+Z(I)*GR
       FT(4,NTP)=FT(4,NTP)+Z(I)*R(I)*GR
       FT(13,NTP)=FT(13,NTP)+GR
       FT(14,NTP)=FT(14,NTP)+R(I)*GR
       FT(15,NTP)=FT(15,NTP)+Z(I)*GR
       FT(16,NTP)=FT(16,NTP)+Z(I)*R(I)*GR
      B(II)=B(II)-RX*(COSA*DZ-SINA*DR)
       GZ= -RX*(COSA*DZ-SINA*DR) *THETA/2.0
       FT(5,NTP)=FT(5,NTP)+GZ
        FT(6,NTP)=FT(6,NTP)+R(I)*GZ
       FT(7,NTP)=FT(7,NTP)+Z(I)*GZ
       FT(8,NTP)=FT(8,NTP)+Z(I)*R(I)*GZ
       FT(17,NTP)=FT(17,NTP)+GZ
       FT(18,NTP)=FT(18,NTP)+R(I)*GZ
```

```
      FT(19,NTP)=FT(19,NTP)+Z(I)*GZ
      FT(20,NTP)=FT(20,NTP)+Z(I)*R(I)*GZ
  620 IF(JJ.LE.0.OR.JJ.GT.ND) GO TO 640
      SINA=0.
      COSA=1.
  630 B(JJ-1)=B(JJ-1)+ZX*(SINA*DZ+COSA*DR)
      GR= ZX*(SINA*DZ+COSA*DR)*THETA/2.0
      FT(1,NTP)=FT(1,NTP)+GR
      FT(2,NTP)=FT(2,NTP)+R(J)*GR
      FT(3,NTP)=FT(3,NTP)+Z(J)*GR
      FT(4,NTP)=FT(4,NTP)+Z(J)*R(J)*GR
      FT(13,NTP)=FT(13,NTP)+GR
      FT(14,NTP)=FT(14,NTP)+R(J)*GR
      FT(15,NTP)=FT(15,NTP)+Z(J)*GR
      FT(16,NTP)=FT(16,NTP)+Z(J)*R(J)*GR
      B(JJ)=B(JJ)-ZX*(COSA*DZ-SINA*DR)
      GZ= -ZX*(COSA*DZ-SINA*DR)*THETA/2.0
      FT(5,NTP)=FT(5,NTP)+GZ
      FT(6,NTP)=FT(6,NTP)+R(J)*GZ
      FT(7,NTP)=FT(7,NTP)+Z(J)*GZ
      FT(8,NTP)=FT(8,NTP)+Z(J)*R(J)*GZ
      FT(17,NTP)=FT(17,NTP)+GZ
      FT(18,NTP)=FT(18,NTP)+R(J)*GZ
      FT(19,NTP)=FT(19,NTP)+Z(J)*GZ
      FT(20,NTP)=FT(20,NTP)+Z(J)*R(J)*GZ
  640 CONTINUE
  701 IF(NUMST.EQ.0) GO TO 700
      DO 680 L=1,NUMST
      I=IT(L)
      J=JT(L)
      RT=ST(L)/6.
      RX=2.*R(I)+R(J)
      ZX=R(I)+2.*R(J)
      XX=SQRT((R(J)-R(I))**2+(Z(J)-Z(I))**2)
      II=3*I-KSHIFT
      JJ=3*J-KSHIFT
      IF(II.LE.0.OR.II.GT.ND) GO TO 670
      B(II)=B(II)+RT*RX*XX
      GT=RT*RX*XX*THETA/2.0
      FT(9,NTP)=FT(9,NTP)+GT
      FT(10,NTP)=FT(10,NTP)+R(I)*GT
      FT(11,NTP)=FT(11,NTP)+Z(I)*GT
      FT(12,NTP)=FT(12,NTP)+Z(I)*R(I)*GT
      FT(21,NTP)=FT(21,NTP)+GT
      FT(22,NTP)=FT(22,NTP)+R(I)*GT
      FT(23,NTP)=FT(23,NTP)+Z(I)*GT
      FT(24,NTP)=FT(24,NTP)+Z(I)*R(I)*GT
  670 IF(JJ.LE.0.OR.JJ.GT.ND) GO TO 680
      B(JJ)=B(JJ)+RT*ZX*XX
      GT=RT*ZX*XX*THETA/2.0
      FT(9,NTP)=FT(9,NTP)+GT
      FT(10,NTP)=FT(10,NTP)+R(J)*GT
      FT(11,NTP)=FT(11,NTP)+Z(J)*GT
      FT(12,NTP)=FT(12,NTP)+Z(J)*R(J)*GT
      FT(21,NTP)=FT(21,NTP)+GT
      FT(22,NTP)=FT(22,NTP)+R(J)*GT
      FT(23,NTP)=FT(23,NTP)+Z(J)*GT
      FT(24,NTP)=FT(24,NTP)+Z(J)*R(J)*GT
  680 CONTINUE
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

```
C     ADD DISPLACEMENT BOUNDARY CONDITIONS
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
  700 DO 750 M=NL,NH
      IDM=0
      IF(M.GT.NUMNP) GO TO 750
      IF(CODE(M).GT.3) GO TO 751
      U=XR(M)
      N=3*M-2-KSHIFT
  752 IF(CODE(M)) 740,750,710
  710 IF(CODE(M).EQ.1) GO TO 720
      IF (CODE(M).EQ.2) GO TO 740
      IF(CODE(M).EQ.3) GO TO 730
      GO TO 740
  720 CALL MODIFY(ND2,N,U)
      CODE(M)=CODE(M)+IDM
      GO TO 750
  730 CALL MODIFY(ND2,N,U)
  740 U=XZ(M)
      N=N+1
      CALL MODIFY(ND2,N,U)
      CODE(M)=CODE(M)+IDM
      GO TO 750
  751 IDM=IDM+4
      U=XT(M)
      N=3*M-KSHIFT
      CALL MODIFY(ND2,N,U)
      U=XR(M)
      N=3*M-2-KSHIFT
      IF(CODE(M).EQ.4) GO TO 750
      CODE(M)=CODE(M)-4
      GO TO 752
  750 CONTINUE
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     WRITE BLOCK OF EQUATIONS ON FORTRAN UNIT AND SHIFT UP LOWER BLOCK
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      WRITE (2) (B(N),(A(N,M),M=1,MBAND),N=1,ND)
      DO 800 N=1,ND
      K=N+ND
      B(N)=B(K)
      B(K)=0.00
      DO 800 M=1,ND
      A(N,M)=A(K,M)
  800 A(K,M)=0.00
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     CHECK FOR LAST BLOCK
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      IF(NM.LT.NUMNP) GO TO 200
      IF(STOP.NE.0.) STOP
 2000 FORMAT (27H  NEGATIVE AREA ELEMENT NO.,I4)
 2001 FORMAT (46H  BAND WIDTH EXCEEDS ALLOWABLE FOR ELEMENT NO.,I4)
      RETURN
      END
      SUBROUTINE STORE
      INTEGER CODE
      COMMON/ANS4/ FT(24,4),GTS1U(24),GTS1UT(24,4)
      COMMON/NXDATA/NTP,NTS,NTOTS,GTS1G(24,24,8)
      COMMON/NXMESH/THETAN(8),NPC(8,8)
      COMMON/NPDATA/R(10   ),CODE(10   ),XR(10   ),Z(10   ),XZ(10   ),
     1NPNUM( 4,   8),T(10   ),XT(10   )
      COMMON/SOLVE/B( 72),A( 72,36),NUMBLK,MBAND
```

```
      COMMON/GLBSEG/FI(24,8),FE(24,8),UC(24,8),SK(24,24,8)
      COMMON/BASIC/ACELZ,ANGVEL,ANGACC,TREF,VOL,NUMNP,NUMEL,NUMPC,NUMSC,
     1NUMST
      COMMON/ANS2/LW(24),R1(24,24),SK1(24,24),DUMM(24,24)
      DIMENSION MW(24)
       DO 50 I=1,24
        DO 50 J=1,24
 50    R1(I,J) = 0.0
      NS = NTP
      DO 110 KK = 1,4
      NP1 = NPC(NS,KK)
      NP2 = NPC(NS,KK+4)
      DO 110 I= 1,3
      R1(3*(KK-1)+I    ,I*4-3  ) = 1.0
      R1(3*(KK-1)+I    ,I*4-2  ) = R(NP1)
      R1(3*(KK-1)+I    ,I*4-1  ) = Z(NP1)
      R1(3*(KK-1)+I    ,I*4    ) = R(NP1) * Z(NP1)
      R1(3*(KK-1)+I+12,I*4+9  ) = 1.0
      R1(3*(KK-1)+I+12,I*4+10) = R(NP2)
      R1(3*(KK-1)+I+12,I*4+11) = Z(NP2)
      R1(3*(KK-1)+I+12,I*4+12) = R(NP2)* Z(NP2)
      UC(3*(KK-1)+I,NS) = B(3*NP1-3+I)
      UC(3*(KK-1)+I+12,NS) = B(3*NP2-3+I)
110   CONTINUE
        CALL MINV(R1,24,D1,LW,MW)
       WRITE(25) ((R1(I,J),J=1,24),I=1,24)
      DO 115 I=1,24
      FE(I,NS)=0.0
       FI(I,NS)=0.0
      DO 115 J=1,24
       FE(I,NS) = FE(I,NS)+ R1(J,I)*FT(J,NTP)
       FI(I,NS) = FI(I,NS) + R1(J,I)*GTS1UT(J,NTP)
       SK1(I,J) = 0.00
      DO 115 K=1,24
      SK1(I,J) = SK1(I,J) + R1(K,I) * GTS1G(K,J,NTP)
115   CONTINUE
      DO 120  I=1,24
      DO 120  J=1,24
      SK(I,J,NS) =0.0
      DO 120  K=1,24
      SK(I,J,NS) = SK(I,J,NS) + SK1(I,K) * R1(K,J)
120   CONTINUE
      RETURN
      END
      SUBROUTINE STRESS
      INTEGER CODE
      COMMON/VISC/EPSDN(12,10,8),SIGVP(6),DEPSR(6,10,8),DELTIM
       COMMON/ANS4/FT(24,4),GTS1U(24) ,GTS1UT(24,4)
      COMMON/BASIC/ACELZ,ANGVEL,ANGACC,TREF,VOL,NUMNP,NUMEL,NUMPC,NUMSC,
     1NUMST
      COMMON/MATP/RO(6),E(12,16,6),EE(16),AOFTS(6)
      COMMON/NPDATA/R(10   ),CODE(10   ),XR(10   ),Z(10   ),XZ(10   ),
     1NPNUM( 4,  8),T(10   ),XT(10   )
      COMMON/ELDATA/BETA(10   ),EPR(10   ),PR(4   ),SH(4   ),IX(8    ,5),
     1IP(4   ),JP(4   ),IS(4   ),JS(4   ),ALPHA(10   ),IT(4   ),JT(4   ),
     2ST(4   )
      COMMON/ARG/RRR(5),ZZZ(5),RR(4),ZZ(4),S(15,15),P(15),TT(6),
     1H(6,15),CRZ(6,6),XI(10),ANGLE(4),SIG(18),EPS(18),N
      COMMON/NONAXI/S1(30,30),P1(30),THETA,BS1(6,30)
      COMMON/NXDATA/NTP,NTS,NTOTS,GTS1G(24,24,8)
```

```
      COMMON/NXMESH/THETAN(8),NPC(8,8)
      COMMON/ARG1/SIG1(18),EPS1(18),DEPSP(12),CEPSP(6,6)
      COMMON/SOLVE/B( 72),A( 72,36),NUMBLK,MBAND
      COMMON/CONVRG/IDONE
      COMMON/RATE/DKPR,SIGPR,BVR,EVR,PSRATE( 10,8),NRATE
      COMMON/PLANE/NPP
      COMMON/RESULT/BS(6,15),D(6,6),C(6,6),AR,BB(6,9),CNS(6,6)
      DIMENSION LM(4),TP(6),TR(3,3),Q(3)
      DIMENSION QQ(3)
      COMMON/DUM1/S1TEM(3,30),GTS1(24,24),TS(6,24)
       DIMENSION P11(24)
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     INITIALIZE
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
       REWIND 3
      XKE=0.
      XPE=0.
      MPRINT=0
      ERROR=.005
      IDONE=1
      NRATE=0
      DO 200 N=1,NUMEL
      IX(N,5)=IABS(IX(N,5))
      CALL QUAD
      MTYPE=IABS(IX(N,5))
      DO 100 I=1,4
      II=3*I
      JJ=3*IX(N,I)
      P1(II-2) = B(JJ-2)
      P1(II-1) = B(JJ-1)
      P1(II   ) = B(JJ   )
      P1(II+10) = B(JJ-2)
      P1(II+11) = B(JJ-1)
      P1(II+12) = B(JJ)
      P(II-2)=B(JJ-2)
      P(II-1)=B(JJ-1)
100   P(II)  =B(JJ)
       READ(3)((GTS1(I,J),J=1,24),I=1,24)
       DO 115 I=1,24
       GTS1U(I)=0.0
       DO 115 J=1,24
  115  GTS1U(I) = GTS1U(I)+ GTS1(I,J)*P1(J)
       DO 116 I=1,24
  116  GTS1UT(I,NTP)=GTS1UT(I,NTP) + GTS1U(I)
      DO 110 I=1,3
110   Q(I)=P(I+12)
      DO 120 I=1,3
      DO 120 J=1,3
120   TR(I,J)=S(I+12,J+12)
      CALL SYMINV(TR,3)
      DO 125 J=1,3
      QQ(J)=0.00
      DO 125 K=1,12
      QQ(J)=QQ(J)+S(J+12,K)*P(K)
 125  CONTINUE
      DO 130 I=1,3
      P(I+12)=0.00
      DO 130 J=1,3
 130  P(I+12)=P(I+12)+TR(I,J)*(Q(J)-QQ(J))
  500 CONTINUE
```

```
      RETURN
      END
      SUBROUTINE SYMINV(A,NMAX)
      DIMENSION A(NMAX,NMAX)
      DO 300 N=1,NMAX
      D=A(N,N)
      DO 100 J=1,NMAX
  100 A(N,J)=-A(N,J)/D
      DO 210 I=1,NMAX
      IF(N.EQ.I) GO TO 210
      DO 200 J=1,NMAX
      IF(N.NE.J) A(I,J)=A(I,J)+A(I,N)*A(N,J)
  200 CONTINUE
  210 A(I,N)=A(I,N)/D
  300 A(N,N)=1.00/D
      RETURN
      END
      SUBROUTINE TEMP(R,Z,T)
      COMMON/SOLVE/X(888),Y(888),TEM(888),NUMTC,MBAND
      DIMENSION SMALL(20),ISM(20)
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     INITIALIZE
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      J=1
      JMAX=16
      IF(NUMTC.LT.JMAX) JMAX=NUMTC
      DO 10 I=1,JMAX
      SMALL(I)=0.
   10 ISM(I)=0
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     FIND THE JMAX CLOSEST POINTS
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      DO 50 I=1,NUMTC
      DSQ=(X(I)-R)**2+(Y(I)-Z)**2
      IF(DSQ.GT..1E-4) GO TO 20
      T=TEM(I)
      RETURN
   20 IF(I.EQ.1) SMALL(1)=DSQ
      IF(I.EQ.1) ISM(1)=1
      IF(I.EQ.1) GO TO 50
      IF(SMALL(J).LE.DSQ.AND.J.LT.JMAX) SMALL(J+1)=DSQ
      IF(SMALL(J).LE.DSQ.AND.J.LT.JMAX) ISM(J+1)=I
      IF(SMALL(J).LE.DSQ) GO TO 40
      DO 30 K=1,J
      JB=J-K +1
      IF(JB.EQ.0) GO TO 40
      SMALL(JB+1)=SMALL(JB)
      ISM(JB+1)=ISM(JB)
      SMALL(JB)=DSQ
      ISM(JB)=I
      IF(JB.EQ.1) GO TO 40
      IF(SMALL(JB-1).LE.DSQ) GO TO 40
   30 CONTINUE
   40 IF(J.LT.JMAX) J=J+1
   50 CONTINUE
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     FIND THE THIRD TEMPERATURE POINT BY AREA TEST
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
      JCHK=JMAX-2
      J=0
```

```
C
C     MATRIX P NOW CONTAINS 15 DISPLACEMENTS FOR QUADRILATERAL ELEMENT
C
C     CALCULATE AVERAGE STRAINS
C
      DO 140 I=1,6
      EPS(I)=0.00
      DO 140 J=1,15
140   EPS(I)=EPS(I)+BS(I,J)*P(J)
C
C     CALCULATE AVERAGE STRESSES
C
      DO 151 I=1,6
      SIG(I)=EPSDN(I,N,NTP)
      DO 151 J=1,6
151   SIG(I)=SIG(I)+CRZ(I,J)*EPS(J)
      DO 152 I=1,6
 152  SIG(I)=SIG(I)-TT(I)
C
C     CALCULATE STRAINS  IN N-S-T COORDINATES
C
      DO 150 I=1,6
      EPS(I+6)=0.00
      DO 150 J=1,6
      DO 150 K=1,6
150   EPS(I+6)=EPS(I+6)+D(I,J)*C(J,K)*EPS(K)
C
C     CALCULATE STRESSES IN N-S-T COORDIATES
C
      DO 160 I=1,6
      SIG(I+6)=EPSDN(I+6,N,NTP)
      DO 160 J=1,6
160   SIG(I+6)=SIG(I+6)+CNS(I,J)*EPS(J+6)
      DO 161 M=1,6
      P(M)=0.00
      DO 161 II=1,3
      IF(AOFTS(MTYPE).EQ.1.) P(M)=CNS(M,II)*EE(II+9)
  161 P(M)=P(M)+(T(N)-TREF)*CNS(M,II)*EE(II+9)
      DO 162 I=1,6
 162  SIG(I+6)=SIG(I+6)-P(I)
C
C
      DO 300 I=1,12
300   EPS(I)=100.0*EPS(I)
      IF(MPRINT.NE.0) GO TO 210
      WRITE(6,2000)
      WRITE(6,2002)
      MPRINT=19
  210 MPRINT=MPRINT-1
      WRITE(6,2001) N,RRR(5),ZZZ(5),(SIG(I),I=1,12)
      WRITE(6,2003) T(N),(EPS(I),I=1,12)
  200 CONTINUE
 2000 FORMAT(129H1   EL      R      Z     SIGMAR   SIGMAZ   SIGMAC   SIGMA
     1RZ  SIGMAZC  SIGMACR  SIGMAN   SIGMAS   SIGMAT   SIGMANS  SIGMAST
     2 SIGMATN)
 2001 FORMAT(1H0,I5,1X,2F7.4,12F9.0)
 2002 FORMAT(128H0         TEMPERATURE     EPSR     EPSZ     EPSC     EPSR
     1Z     EPSZC     EPSCR     EPSN     EPSS     EPST     EPSNS     EPSST
     2  EPSTN)
 2003 FORMAT(6X,F13.0,2X,12F9.5)
```

```
      I1=ISM(1)
      I2=ISM(2)
   60 I3=ISM(J+3)
      AREA=.50*(Y(I1)*X(I3)-Y(I3)*X(I1)+Y(I3)*X(I2)-Y(I2)*X(I3)+
     1         Y(I2)*X(I1)-Y(I1)*X(I2))
      D1=(X(I2)-X(I1))**2+(Y(I2)-Y(I1))**2
C     IF D1 IS APPROXIMATELY 0. IT IS ASSUMED THAT THERE EXISTS A
C     DUPLICATION OF INPUT
      IF(D1.GT..1E-3) GO TO 70
      I2=I3
      J=J+1
      GO TO 60
   70 IF(AREA**2.GT..1*D1*SMALL(1)) GO TO 80
      J=J+1
      IF(J.LT.JCHK) GO TO 60
      WRITE(6,2000) I1,I2,I3,J
      T=TEM(I1)
      RETURN
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
C     FIND TEMPERATURE INTERCEPT
C* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
   80 DETA=Y(I1)*(TEM(I3)-TEM(I2))+Y(I2)*(TEM(I1)-TEM(I3))
     1      +Y(I3)*(TEM(I2)-TEM(I1))
      DETB=X(I1)*(TEM(I2)-TEM(I3))+X(I2)*(TEM(I3)-TEM(I1))
     1      +X(I3)*(TEM(I1)-TEM(I2))
      DETC=TEM(I1)*(X(I2)*Y(I3)-X(I3)*Y(I2))+TEM(I2)*(X(I3)*Y(I1)-X(I1)*
     1Y(I3))+TEM(I3)*(X(II)*Y(I2)-X(I2)*Y(II))
      T=(DETA*R+DETB*Z+DETC)/(2.*AREA)
 2000 FORMAT (28H  ERROR IN TEMPERATURE INPUT,5H  I1=I4,5H  I2=I4,
     15H  I3=I4,4H  J=I4)
      RETURN
      END
      SUBROUTINE TEM2(NUMNP)
      INTEGER CODE
      COMMON/NPDATA/R(10  ),CODE(10  ),XR(10  ),Z(10  ),XZ(10  ),
     1NPNUM( 4,  8),T(10  ),XT(10  )
      READ(5,1000) TCONST
      DO 100 N=1,NUMNP
  100 T(N)=TCONST
 1000 FORMAT(F10.0)
      RETURN
      END
      SUBROUTINE TRISTF (II,JJ,KK)
      INTEGER CODE
      COMMON/VISC/EPSDN(12,10,8),SIGVP(6),DEPSR(6,10,8),DELTIM
       COMMON/PLAS/ALFA(6,  4,8),SIGYLD(7,6,8),IFGPL(  4,8)
      COMMON/NXDATA/NTP,NTS,NTOTS,GTS1G(24,24,8)
      COMMON/MATP/RO(6),E(12,16,6),EE(16),AOFTS(6)
      COMMON/BASIC/ACELZ,ANGVEL,ANGACC,TREF,VOL,NUMNP,NUMEL,NUMPC,NUMSC,
     1NUMST
      COMMON/ARG/RRR(5),ZZZ(5),RR(4),ZZ(4),S(15,15),P(15),TT(6),
     1H(6,15),CRZ(6,6),XI(10),ANGLE(4),SIG(18),EPS(18),N
      COMMON/NPDATA/R(10  ),CODE(10  ),XR(10  ),Z(10  ),XZ(10  ),
     1NPNUM( 4,  8),T(10  ),XT(10  )
      COMMON/ELDATA/BETA(10  ),EPR(10  ),PR(4  ),SH(4  ),IX(8  ,5),
     1IP(4  ),JP(4  ),IS(4  ),JS(4  ),ALPHA(10  ),IT(4  ),JT(4  ),
     2ST(4  )
      COMMON/NONAXI/S1(30,30),P1(30),THETA,BS1(6,30)
      COMMON/RESULT/BS(6,15),D(6,6),C(6,6),AR,BB(6,9),CNS(6,6)
      DIMENSION B1A(6,9),B1B(6,9),B2A(6,9),B2B(6,9),B3A(6,9),B3B(6,9)
```

```
      DIMENSION B1(6,9),B2(6,9),B3(6,9),F(6,7),G(9,6),V(9,9)
      DIMENSION BF(3),BFR(3),BFZ(3),TP(9),B(9,9),TVP(9)
      MTYPE=IABS(IX(N,5))
      RR(1)=RRR(II)
      RR(2)=RRR(JJ)
      RR(3)=RRR(KK)
      ZZ(1)=ZZZ(II)
      ZZ(2)=ZZZ(JJ)
      ZZ(3)=ZZZ(KK)
      CALL INTER
      VOL=VOL+XI(1)
      COMM=RR(2)*(ZZ(3)-ZZ(1))+RR(1)*(ZZ(2)-ZZ(3))+RR(3)*(ZZ(1)-ZZ(2))
       DO 10 I=1,6
       DO 10 J=1,9
      B1(I,J)=0.00
      B2(I,J)=0.00
 10   B3(I,J)=0.00
C     FILL B1 MATRIX-CONSTANT TERMS
      B1(1,1)=(ZZ(2)-ZZ(3))/COMM
      B1(1,4)=(ZZ(3)-ZZ(1))/COMM
      B1(1,7)=(ZZ(1)-ZZ(2))/COMM
      B1(3,1)=B1(1,1)
      B1(3,4)=B1(1,4)
      B1(3,7)=B1(1,7)
      B1(2,2)=(RR(3)-RR(2))/COMM
      B1(2,5)=(RR(1)-RR(3))/COMM
      B1(2,8)=(RR(2)-RR(1))/COMM
      B1(4,1)=B1(2,2)
      B1(4,4)=B1(2,5)
      B1(4,7)=B1(2,8)
      B1(4,2)=B1(1,1)
      B1(4,5)=B1(1,4)
      B1(4,8)=B1(1,7)
      B1(5,3)=B1(4,1)
      B1(5,6)=B1(4,4)
      B1(5,9)=B1(4,7)
C     FILL B2 MATRIX-1/R TERMS
      B2(3,1)=(1/COMM)*((ZZ(3)-ZZ(2))*RR(2)+(RR(2)-RR(3))*ZZ(2))
      B2(3,4)=(1/COMM)*((ZZ(1)-ZZ(3))*RR(3)-(RR(1)-RR(3))*ZZ(3))
      B2(3,7)=(1/COMM)*((ZZ(2)-ZZ(1))*RR(1)+(RR(1)-RR(2))*ZZ(1))
      B2(6,3)=-B2(3,1)
      B2(6,6)=-B2(3,4)
      B2(6,9)=-B2(3,7)
C     FILL B3 MATRIX-Z/R TERMS
      B3(3,1)=(RR(3)-RR(2))/COMM
      B3(3,4)=(RR(1)-RR(3))/COMM
      B3(3,7)=(RR(2)-RR(1))/COMM
      B3(6,3)=(RR(2)-RR(3))/COMM
      B3(6,6)=(RR(3)-RR(1))/COMM
      B3(6,9)=(RR(1)-RR(2))/COMM
      AR=AR+XI(1)
      DO 80 I=1,6
      DO 80 J=1,9
80    BB(I,J)=B1(I,J)*XI(1)+B2(I,J)*XI(2)+B3(I,J)*XI(4)
      DO 81 K=1,6
      DO 81 I=1,3
      BS(K,3*JJ-3+I)=BB(K,I+3)+BS(K,3*JJ-3+I)
      BS(K,3*II-3+I)=BB(K,I)+BS(K,3*II-3+I)
81    BS(K,3*KK-3+I)=BB(K,I+6)+BS(K,3*KK-3+I)
      DO 220  I=1,6
```

```
      DO 220 J=1,9
      B1A(I,J)=B1(I,J)*XI(1)+B2(I,J)*XI(2)+B3(I,J)*XI(4)
      B2A(I,J)=B1(I,J)*XI(2)+B2(I,J)*XI(3)+B3(I,J)*XI(5)
      B3A(I,J)=B1(I,J)*XI(4)+B2(I,J)*XI(5)+B3(I,J)*XI(6)
  220  CONTINUE
      DO 200 I=1,6
      DO 200 K=1,9
      B1B(I,K)=0.0
      B2B(I,K)=0.0
      B3B(I,K)=0.0
      DO 200 J=1,6
      B1B(I,K)=B1B(I,K)+CRZ(I,J)*B1A(J,K)
      B2B(I,K)=B2B(I,K)+CRZ(I,J)*B2A(J,K)
      B3B(I,K)=B3B(I,K)+CRZ(I,J)*B3A(J,K)
  200  CONTINUE
      DO 230 I=1,9
      DO 230 K=1,9
      B(I,K)=0.0
      DO 230 J=1,6
      B(I,K)=B(I,K)+B1(J,I)*B1B(J,K)+B2(J,I)*B2B(J,K)+B3(J,I)*B3B(J,K)
  230   CONTINUE
C     ASSEMBLE QUADRILATERAL STIFFNESS MATRIX, S, FROM TRIANGULAR
C     STIFFNESS MATRIX, B.
      IIM=3*II-3
      JJM=3*JJ-3
      KKM=3*KK-3
      DO 120 I=1,3
      DO 120 J=1,3
      S(IIM+I,IIM+J)=B(I  ,J  )+S(IIM+I,IIM+J)
      S(IIM+I,JJM+J)=B(I  ,J+3)+S(IIM+I,JJM+J)
      S(IIM+I,KKM+J)=B(I  ,J+6)+S(IIM+I,KKM+J)
      S(JJM+I,IIM+J)=B(I+3,J  )+S(JJM+I,IIM+J)
      S(JJM+I,JJM+J)=B(I+3,J+3)+S(JJM+I,JJM+J)
      S(JJM+I,KKM+J)=B(I+3,J+6)+S(JJM+I,KKM+J)
      S(KKM+I,IIM+J)=B(I+6,J  )+S(KKM+I,IIM+J)
      S(KKM+I,JJM+J)=B(I+6,J+3)+S(KKM+I,JJM+J)
      S(KKM+I,KKM+J)=B(I+6,J+6)+S(KKM+I,KKM+J)
  120 CONTINUE
C     ASSEMBLE BODY FORCES MATRIX
      BF(1)=(ZZ(3)*RR(2)-RR(3)*ZZ(2))/COMM
      BF(2)=(ZZ(1)*RR(3)-RR(1)*ZZ(3))/COMM
      BF(3)=(ZZ(2)*RR(1)-RR(2)*ZZ(1))/COMM
      BFR(1)=(ZZ(2)-ZZ(3))/COMM
      BFR(2)=(ZZ(3)-ZZ(1))/COMM
      BFR(3)=(ZZ(1)-ZZ(2))/COMM
      BFZ(1)=(RR(3)-RR(2))/COMM
      BFZ(2)=(RR(1)-RR(3))/COMM
      BFZ(3)=(RR(2)-RR(1))/COMM
C     BODY FORCE IN Z-DIRECTION
      COMM=-ACELZ*RO(MTYPE)
      DO 140 I=1,3
      IIK=3*I-1
  140 TP(IIK)=COMM*(BF(I)*XI(1)+BFR(I)*XI(7)+BFZ(I)*XI(8))
C     BODY FORCE IN R-DIRECTION
      COMM=ANGVEL**2*RO(MTYPE)
      DO 150 I=1,3
      L=3*I-2
  150 TP(L)=COMM*(BF(I)*XI(7)+BFR(I)*XI(9)+BFZ(I)*XI(10))
C     BODY FORCES IN TANG. DIRECTION
      COMM=-ANGACC*RO(MTYPE)
```

```
      DO 160 I=1,3
      IIM=3*I
  160 TP(IIM)=COMM*(BF(I)*XI(7)+BFR(I)*XI(9)+BFZ(I)*XI(10))
C     ADD THERMAL EFFECTS
      DO 161 J=1,9
      DO 161 K=1,6
 161  TP(J)=TP(J)+(XI(1)*B1(K,J)+XI(2)*B2(K,J)
     1+XI(4)*B3(K,J))*TT(K)
C     REARRANGE TP INTO P-MATRIX,THE BODY FORCES MATRIX
      K=3*II-2
      L=3*JJ-2
      M=3*KK-2
      DO 170 I=1,3
      J=I-1
      P1(K+J    ) = P1(K+J    )+TP(I   )*THETA/2.0 +TP(I+6)*THETA/4.0
      P1(K+J+15) = P1(K+J+15)+TP(I   )*THETA/2.0+TP(I+6)*THETA/4.0
      P1(L+J    ) = P1(L+J    )+TP(I+3)*THETA/2.0+TP(I+6)*THETA/4.0
      P1(L+J+15) = P1(L+J+15)+TP(I+3)*THETA/2.0+TP(I+6)*THETA/4.0
      P1(M+J    ) = P1(M+J    )+TP(I+6)*THETA/2.0
      P1(M+J+15) = P1(M+J+15)+TP(I+6)*THETA/2.0
      P(K+J)=P(K+J)+TP(I)
      P(L+J)=P(L+J)+TP(I+3)
  170 P(M+J)=P(M+J)+TP(I+6)
       IF(IFGPL(N,NTP).EQ.0) GO TO 190
       DO 174 I=1,9
       TVP(I)=0.0
       DO 174 J=1,6
       TVP(I)=TVP(I)+BB(J,I)*EPSDN(J,N,NTP)
  174  CONTINUE
       DO 180 I=1,3
       J=I-1
       P(K+J)=P(K+J)-TVP(I)
       P(L+J)=P(L+J)-TVP(I+3)
  180  P(M+J)=P(M+J)-TVP(I+6)
  190 CONTINUE
      RETURN
      END
      SUBROUTINE XMODFY(U,N)
      COMMON/NXSOLV/SK (36 ,24),R1 (132),FTOT(132),NSZF
       NBAND=24
      DO 10 M=2,NBAND
      K=N-M+1
      IF(K.LE.0) GO TO 5
      R1(K)=R1(K)-SK(K,M)*U
      SK(K,M)=0.
    5 K=N+M-1
      IF(NSZF.LT.K) GO TO 10
      R1(K)=R1(K)-SK(N,M)*U
      SK(N,M)=0.
   10 CONTINUE
      SK(N,1)=1.
      R1(N)=U
      RETURN
      END
       SUBROUTINE XSOLVE
      COMMON/NXSOLV/SK (36 ,24),R1 (132),FTOT(132),NSZF
       NBAND=24
      DO 300 N=1,NSZF
      I=N
      DO 290 L=2,NBAND
```

```
      I=I+1
      IF(SK(N,L)) 240,290,240
  240 AC=SK(N,L)/SK(N,1)
      J=0
      DO 270 K=L,NBAND
      J=J+1
      IF(SK(N,K)) 260,270,260
  260 SK(I,J)=SK(I,J)-AC*SK(N,K)
  270 CONTINUE
  280 SK(N,L)=AC
C
      R1(I)=R1(I)-AC*R1(N)
  290 CONTINUE
  300 R1(N)=R1(N)/SK(N,1)
C
      N=NSZF
  350 N=N-1
      IF(N) 500,500,360
  360 L=N
      DO 400 K=2,NBAND
      L=L+1
      IF(SK(N,K)) 370,400,370
  370 R1(N)=R1(N)-SK(N,K)*R1(L)
  400 CONTINUE
      GO TO 350
C
  500 RETURN
      END
      SUBROUTINE YIELD(N,NS,MTYPE)
      DIMENSION DALFA(6),SIGYB(3)
      COMMON/PLAS/ALFA(6,  4,8),SIGYLD(7,6,8),IFGPL(   4,8)
      COMMON/INCR/NOLINC,NOL,INERT,NUMMAT,SIGTOT(12,   4,8)
     1,EPSTOT(12,  4,8)
      COMMON/ARG1/SIG1(18),EPS1(18),DEPSP(12),CEPSP(6,6)
       C=SIGYLD(7,MTYPE,NS)
      DO 50 I=1,6
   50 ALFA(I,N,NS)=ALFA(I,N,NS)+C*DEPSP(I+6)
C     WRITE(6,1000)N,NS
C1000 FORMAT(" "," ALFA FOR EL ",I5," SEGMENT", I5)
C     WRITE(6,1100)(ALFA(I,N,NS),I=1,6)
 1100 FORMAT(" ",6E12.6)
      DO 100 I=1,6
  100  SIG1(I)=SIGTOT(I+6,N,NS)-ALFA(I,N,NS)
C GET COMBINATION YIELD STRESSES
      SIGYB(1)=1./SIGYLD(1,MTYPE,NS)**2-1./SIGYLD(2,MTYPE,NS)**2
     1       -1./SIGYLD(3,MTYPE,NS)**2
      SIGYB(2)= 1./SIGYLD(2,MTYPE,NS)**2-1./SIGYLD(1,MTYPE,NS)**2
     1         -1./SIGYLD(3,MTYPE,NS)**2
      SIGYB(3) = 1./SIGYLD(3,MTYPE,NS)**2-1./SIGYLD(2,MTYPE,NS)**2
     1         -1./SIGYLD(1,MTYPE,NS)**2
C       TEST YIELD CRITERION *********
      TEST=0.0
      DO 200  I=1,6
  200  TEST=TEST+SIG1(I)**2/SIGYLD(I,MTYPE,NS)**2
      TEST=TEST+ SIGYB(1)*SIG1(2)*SIG1(3) +SIGYB(2)*SIG1(1)*SIG1(3)
     1          +SIGYB(3)*SIG1(1)*SIG1(2)
      IFGPL(N,NS)=0
      IF (TEST.LE.1.0) GO TO 500
       IFGPL(N,NS)=1
  500 RETURN
```

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